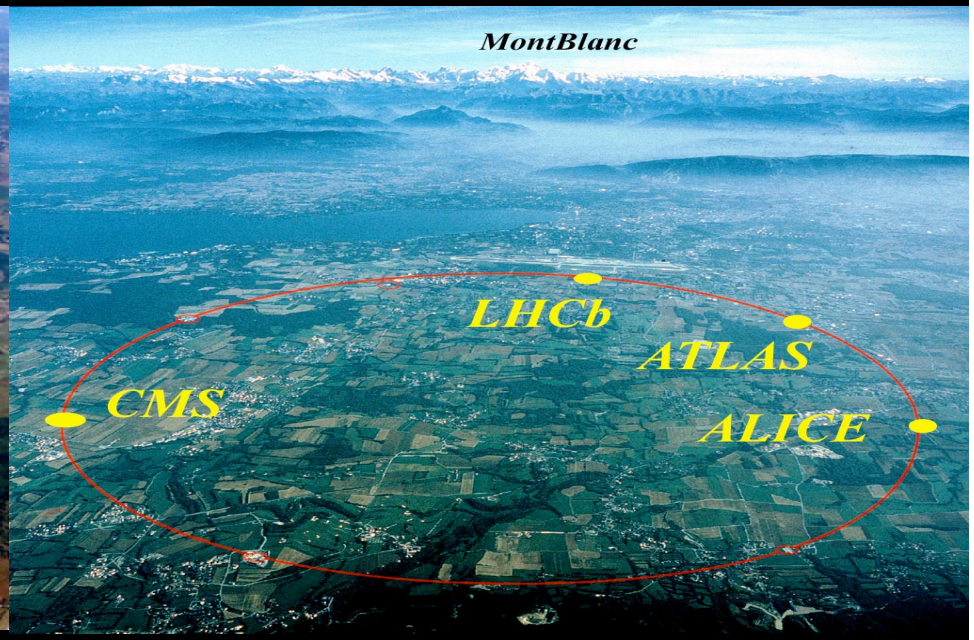
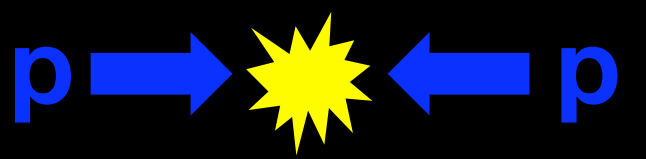
Results from the Tevatron and LHC Prospects



$\sqrt{s}$=1.96 TeV

$\sqrt{s}\approx$14 TeV



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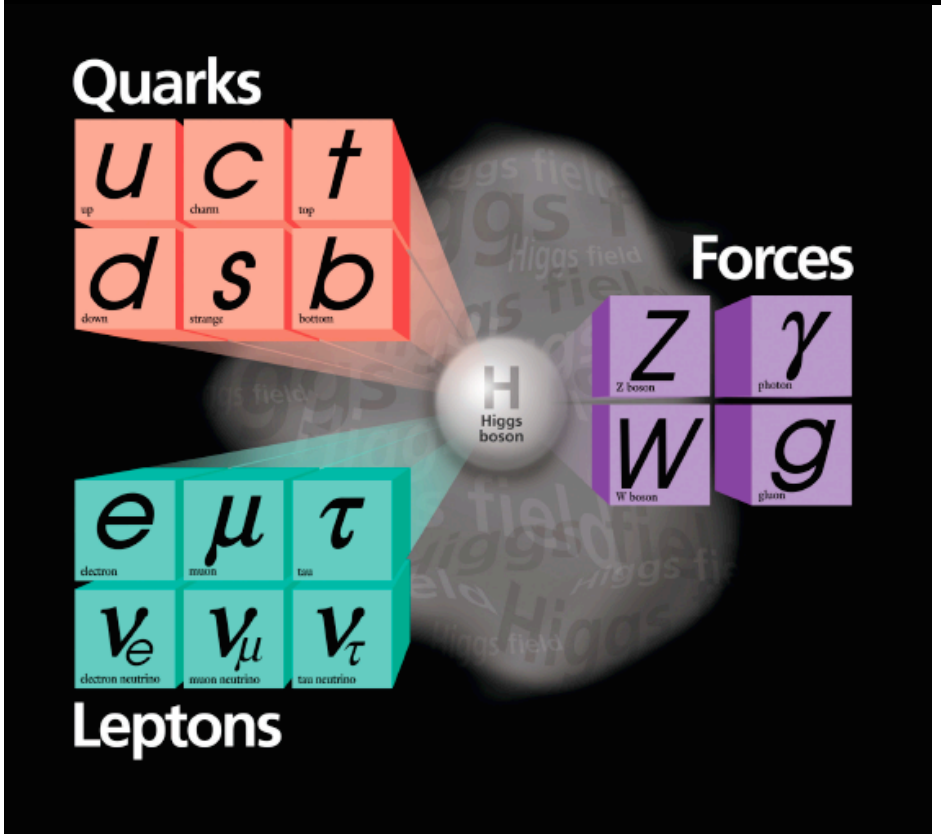
University of California, Berkeley and Lawrence Berkeley National Laboratory

PASCOS, Hamburg, July 2009

The Standard Model and the Standard Questions We Have

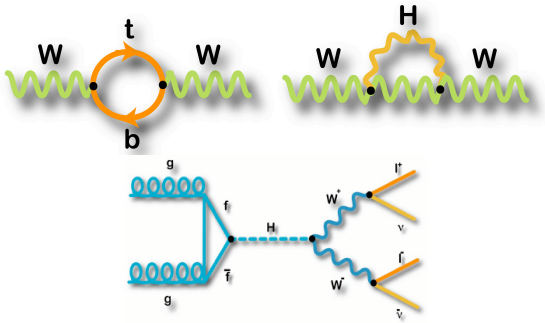


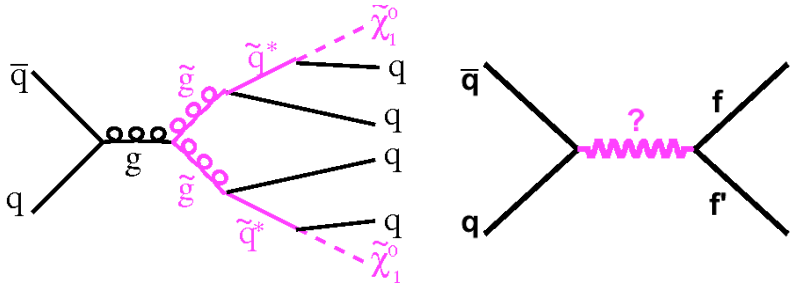
- What is the origin of electroweak symmetry breaking?
  - Is there a Higgs boson?
  - WHERE IS IT?
- What is the Dark Matter?
  - Is it produced at colliders?
- Is Nature supersymmetric?
- Are there new dimensions of space?
- Is there anything maybe that nobody has thought of and no one has looked for and we missed it?

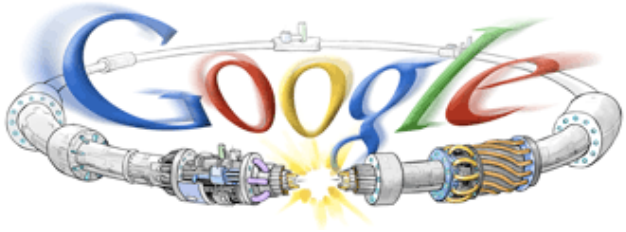
- Hierarchy problem:
  - New physics should be at the TeV scale!

Outline

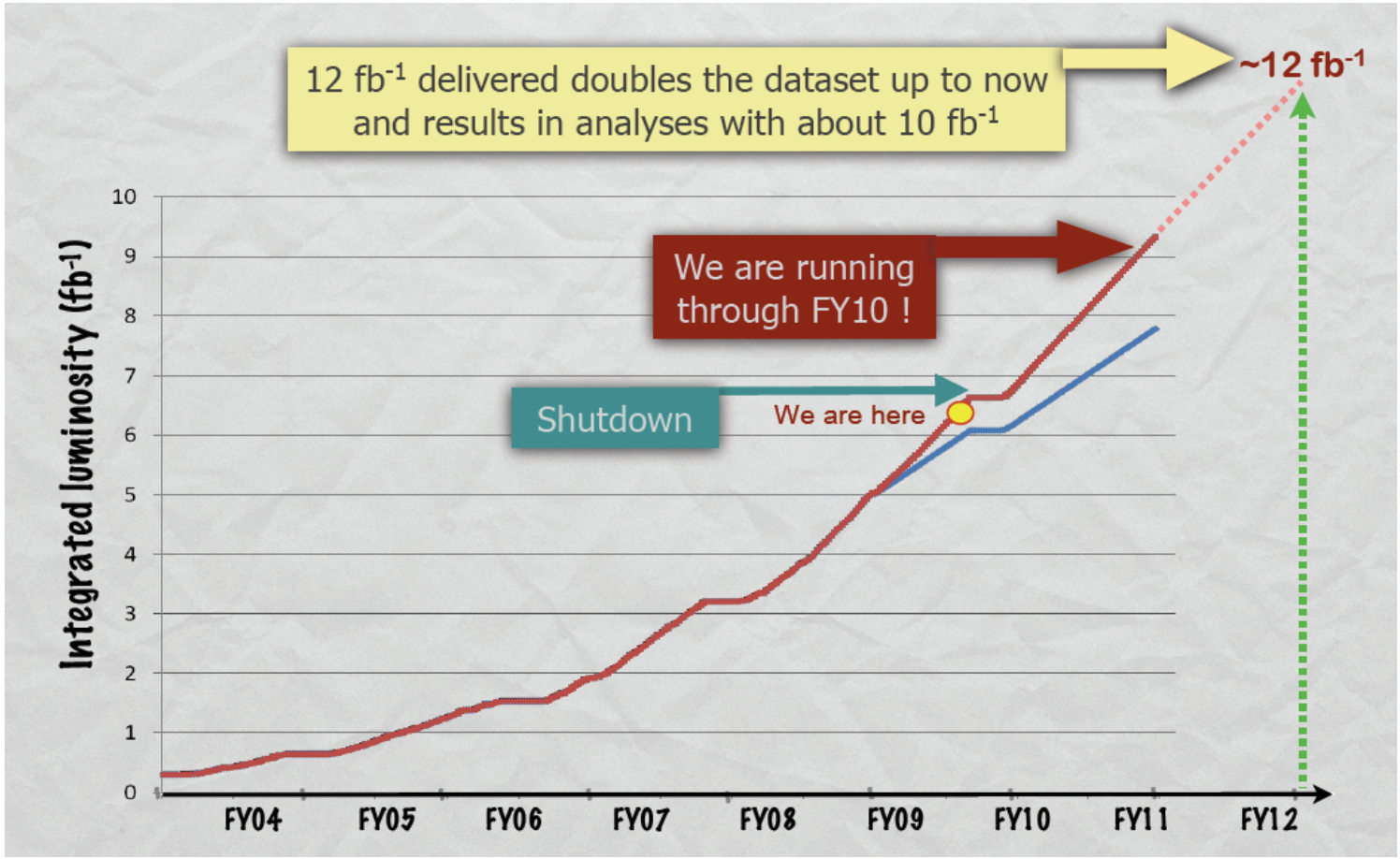
- **Tevatron Results**
  - **Electroweak Symmetry Breaking**
    - W boson and top quark mass
    - Higgs boson search
  - **Beyond the Standard Model**
    - Supersymmetry
    - Resonances: Z', W' etc.
- **LHC Status**
  - **Status of accelerator and detectors**
  - **Physics perspectives with early data**
- **Conclusions and Outlook**







Tevatron Status

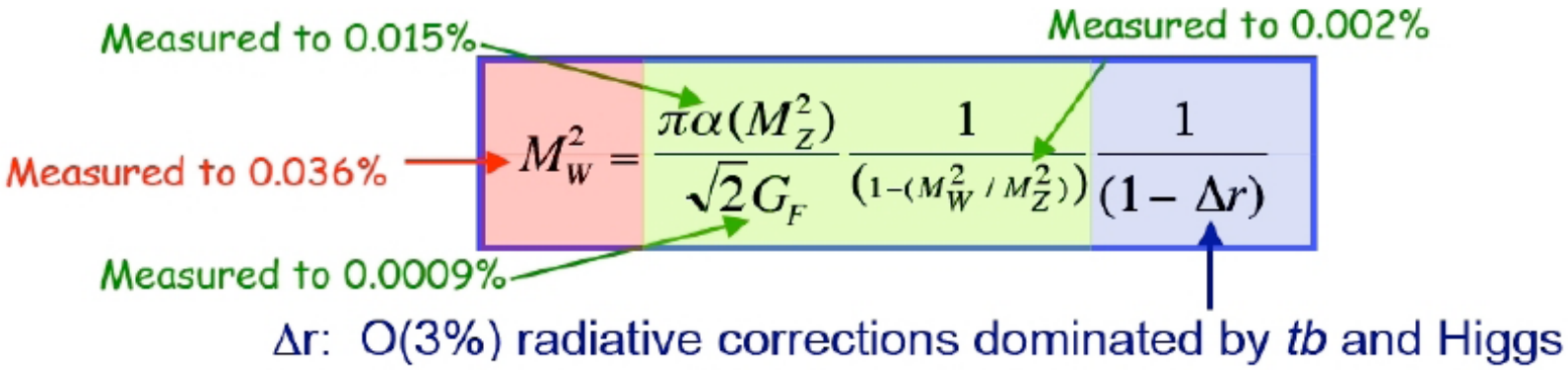


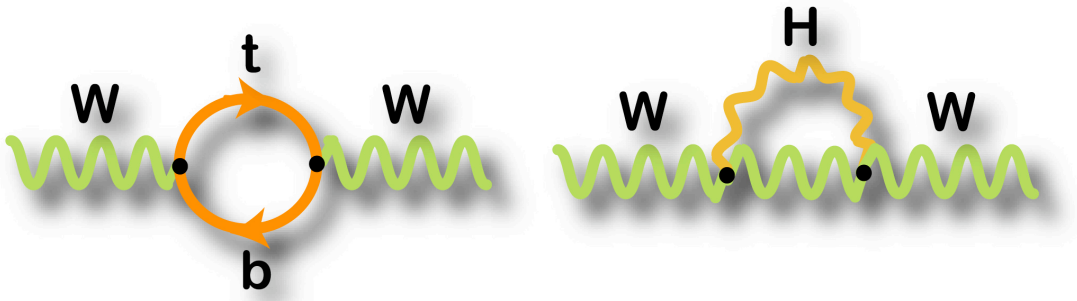
(from J. Konigsberg)

- **Luminosity up to now 7 fb^{-1}**
  - **Running in 2010 approved => 9 fb^{-1}**
  - **Running in 2011 considered => 12 fb^{-1}**

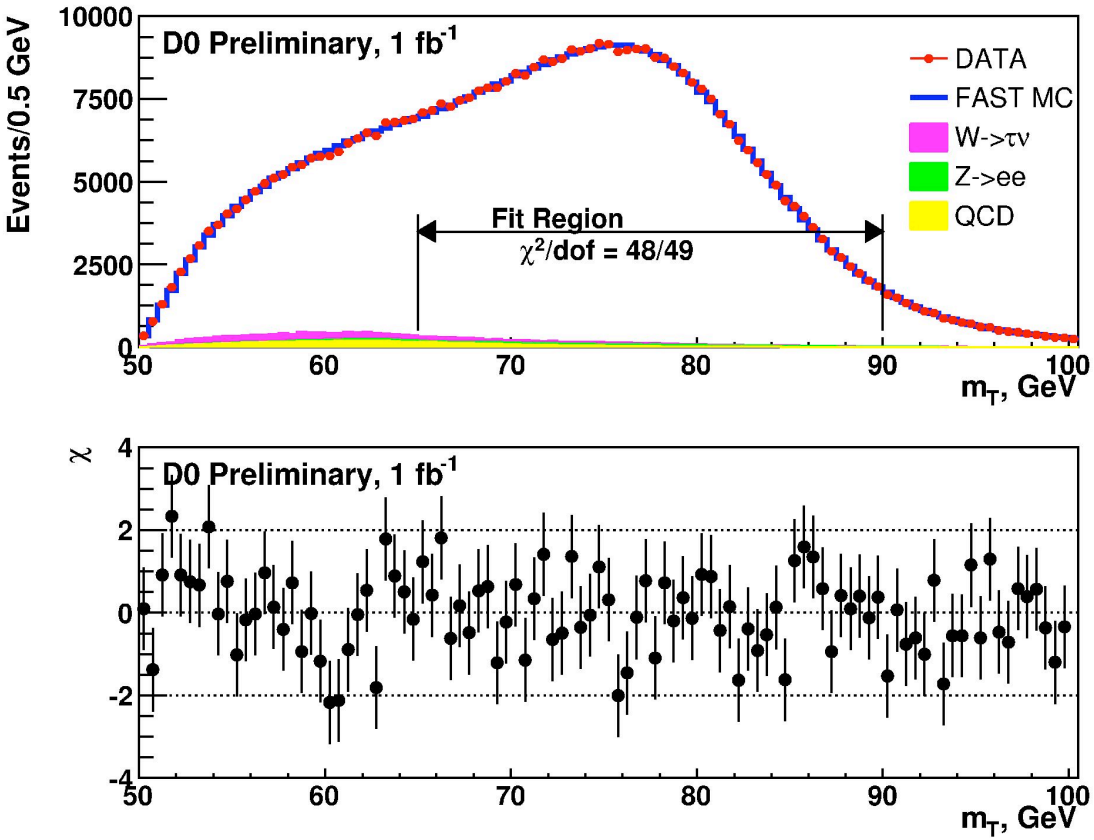
The Electroweak Precision Data

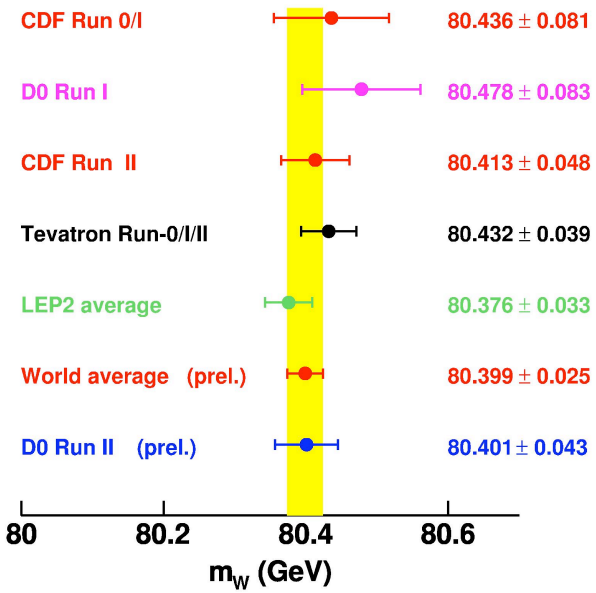
- **Precision measurements of**
  - muon decay constant and α
  - Z boson properties (LEP,SLD)
  - W boson mass (LEP+Tevatron)
  - Top quark mass (Tevatron)





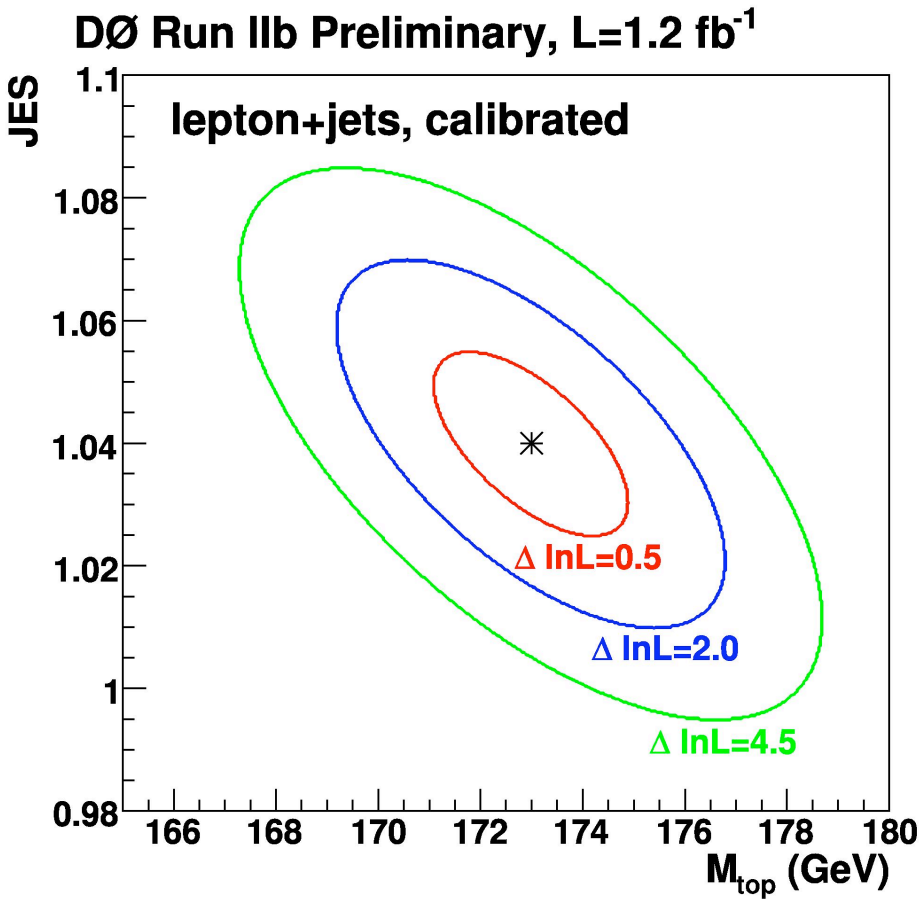
W Boson Mass

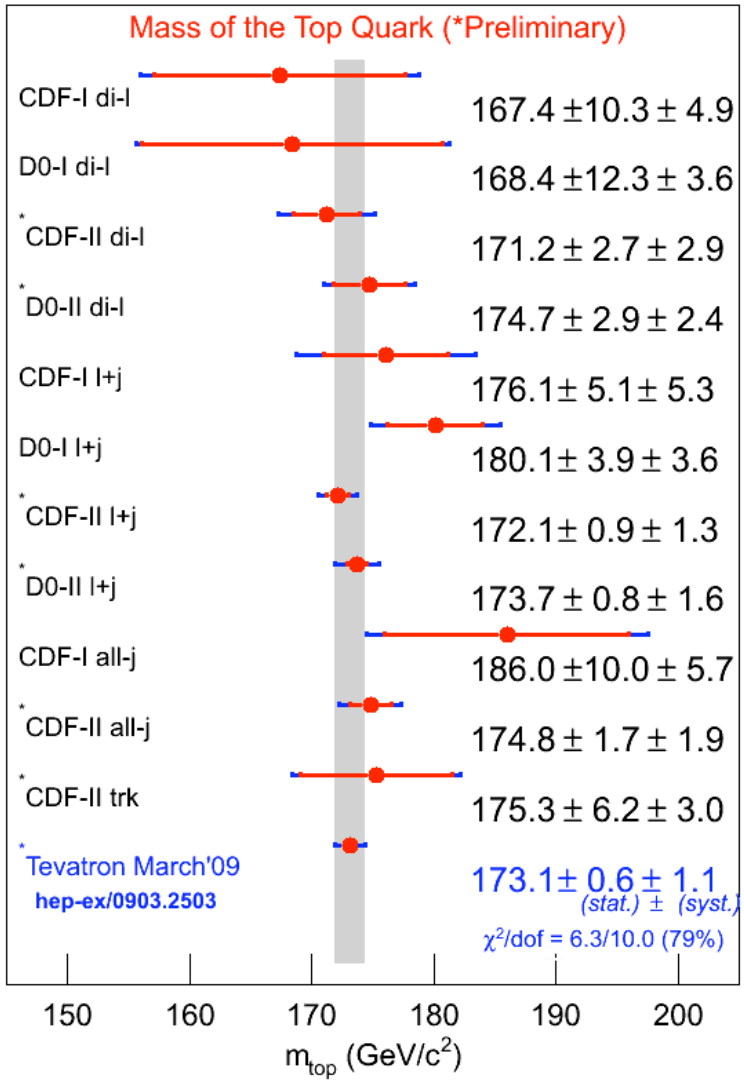




- New World average: **M_W=80399 ± 23 MeV**
- Ultimate Run 2 precision: **~15-20 MeV**

Top Quark Mass Results



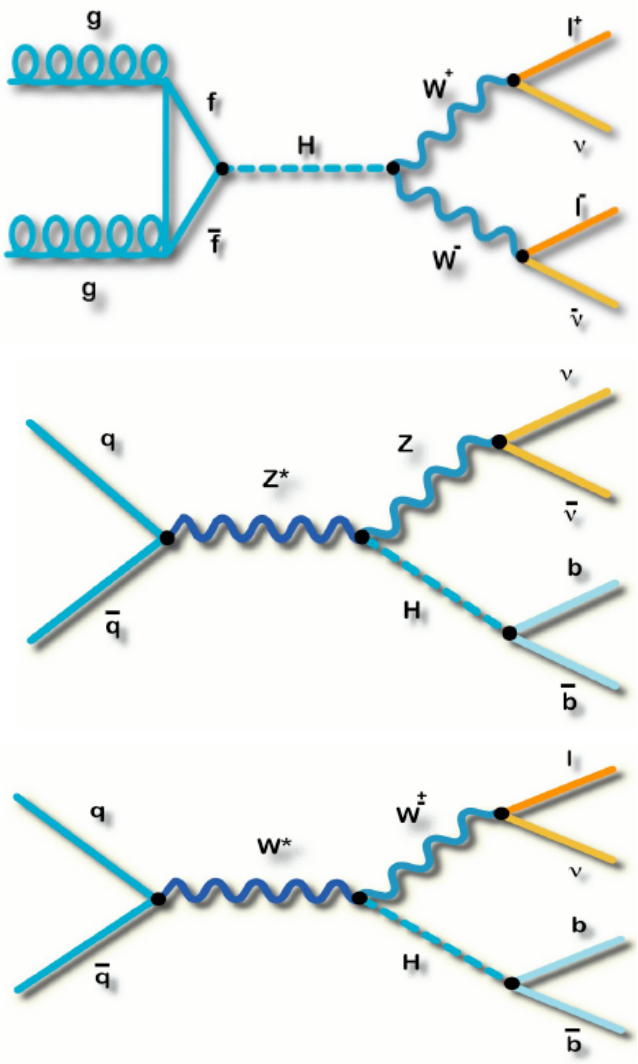


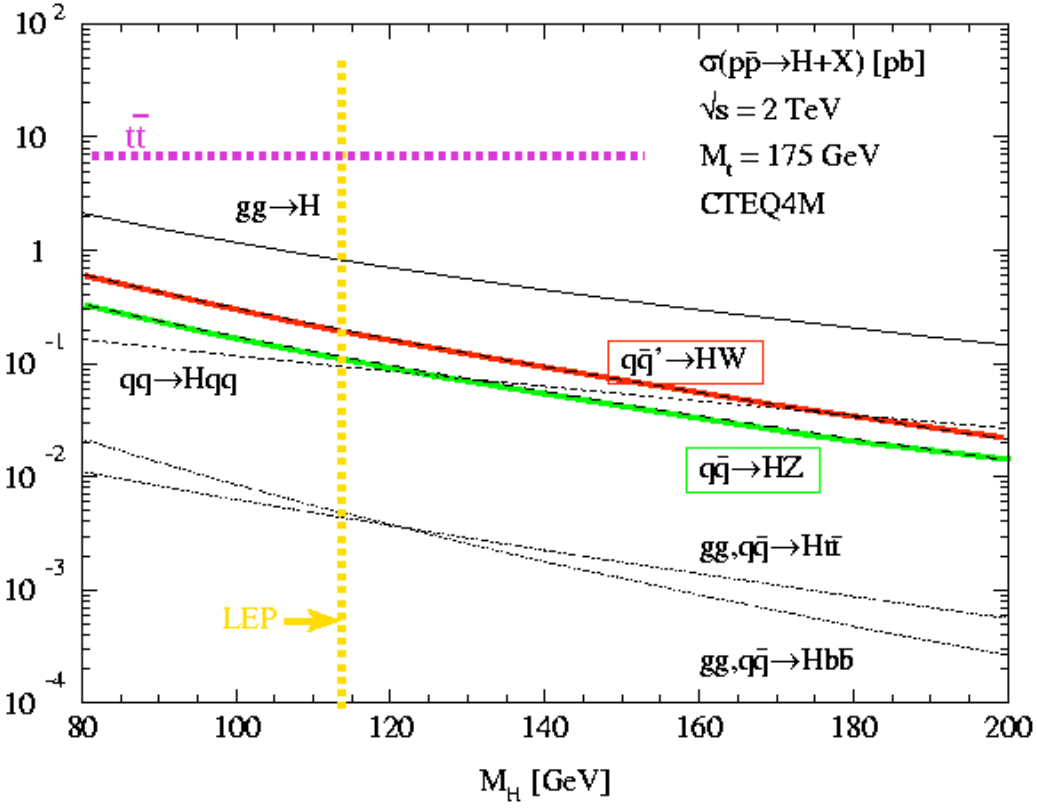
m_{top}=173.1± 1.2 GeV/c^2

Dominant systematic uncertainties:

MC modelling and jet energy calibration for b-jets

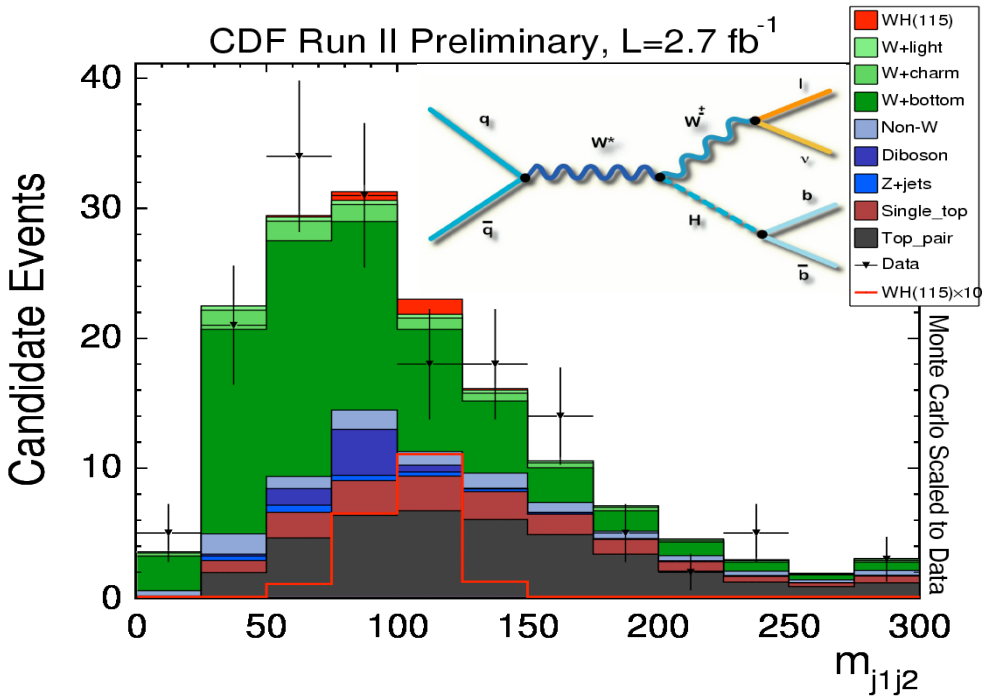
Higgs Production at the Tevatron

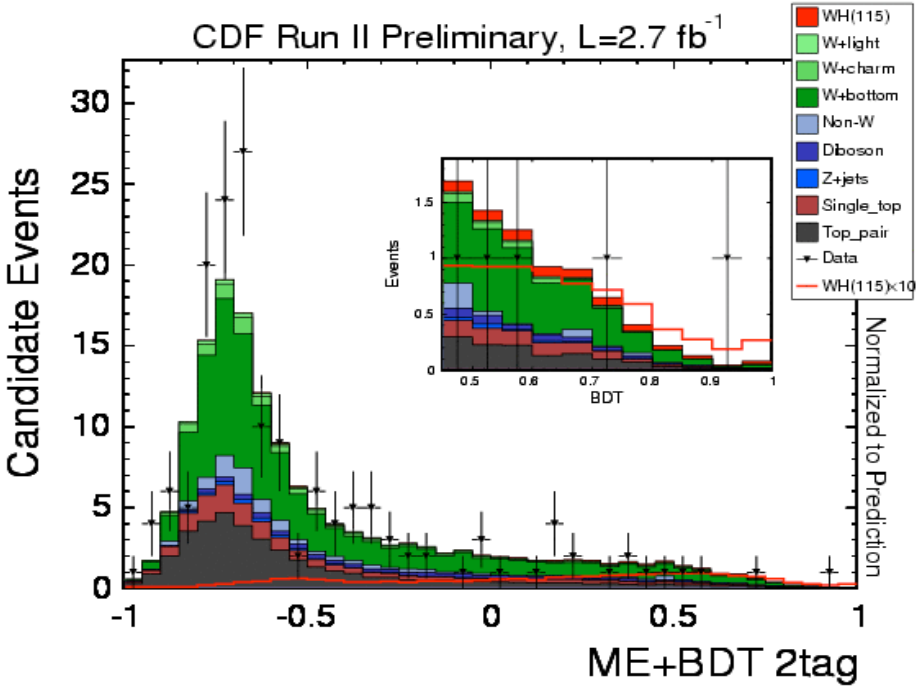




- Dominant **gg->H**
- Subdominant **WH, ZH**

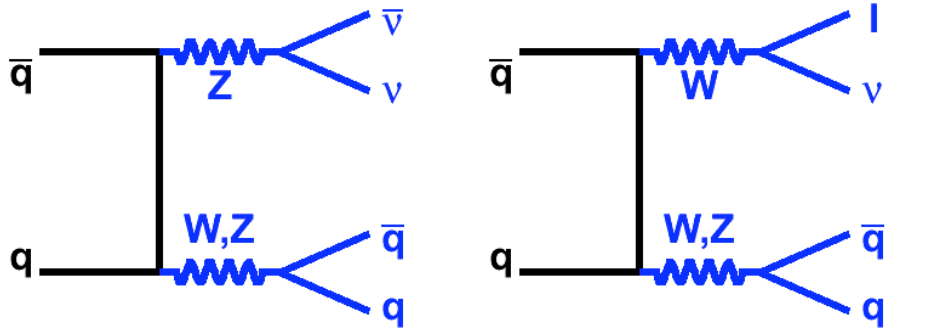
W+Higgs with H→bb

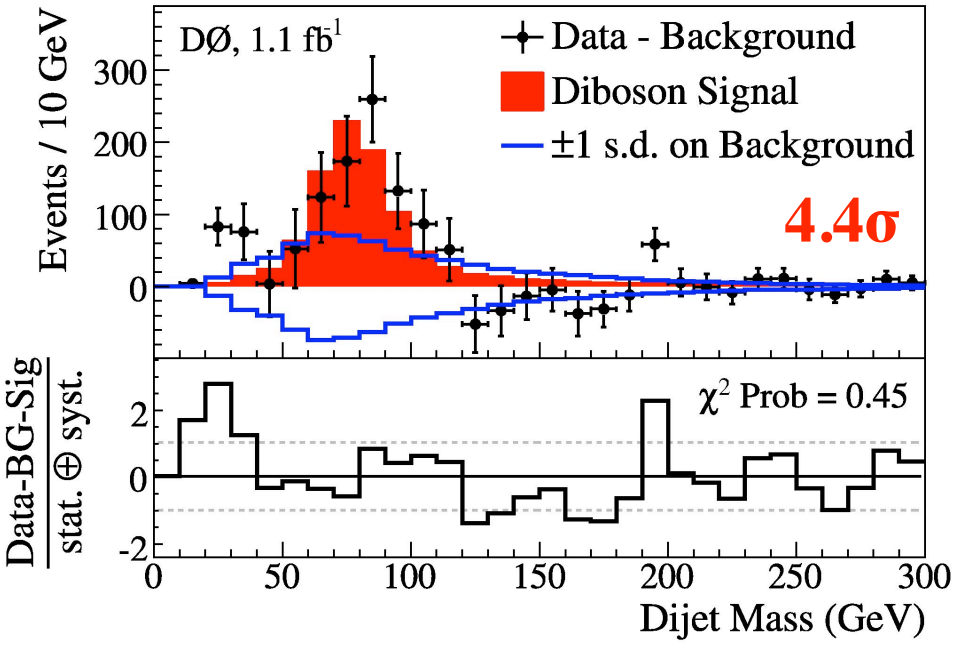


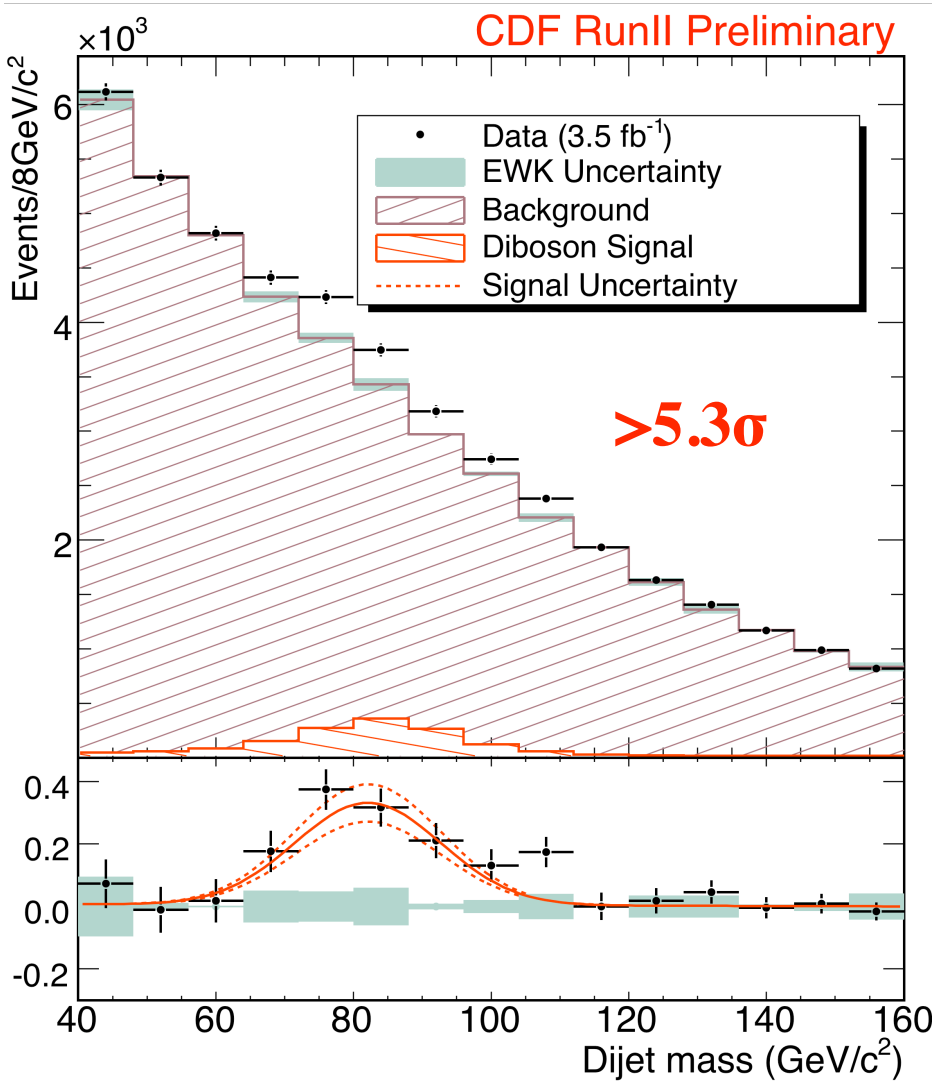


- Search for really small signal on top of difficult backgrounds:
  - Peak in invariant mass of two b-jets not sufficient to discriminate
  - Analyses based on advanced analysis techniques
    - Neural Networks, Boosted Decision trees, etc
- Both collaborations have analyzed nearly 3 fb^{-1} in all 3 modes:
  - WH→lνbb, ZH →llbb, ZH →ννbb

Dibosons → lνjj and ννjj



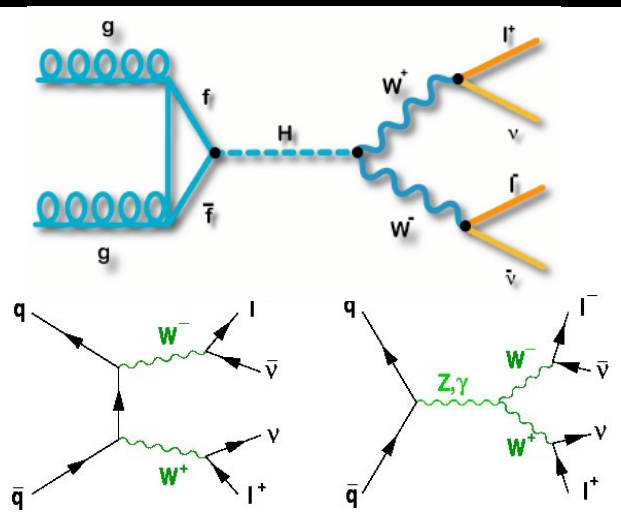


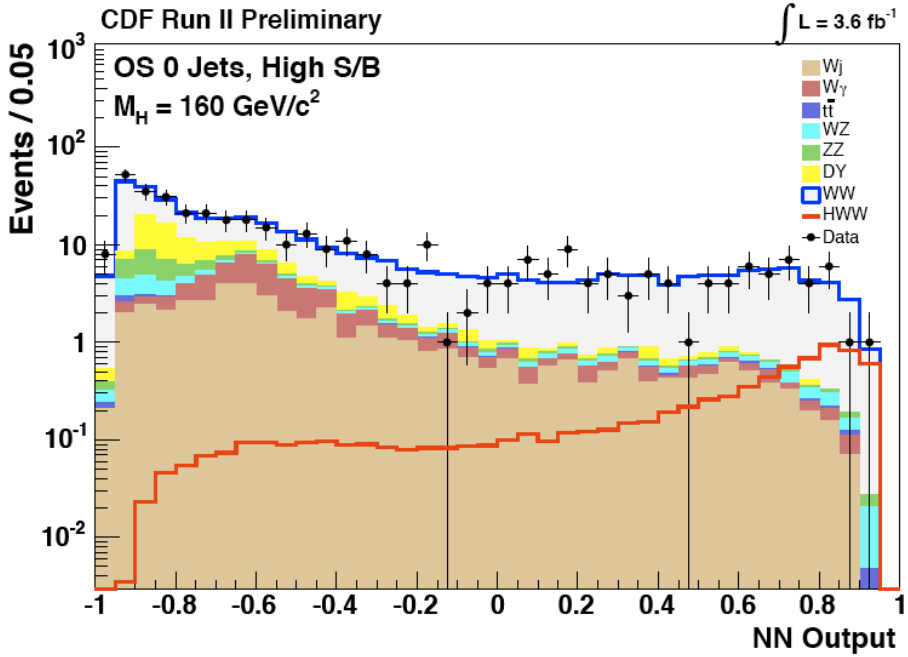


- Observation and Evidence:
  - Important milestones on road to low mass Higgs boson search

$H \rightarrow WW^{(*)} \rightarrow l^+l^-\nu\nu$

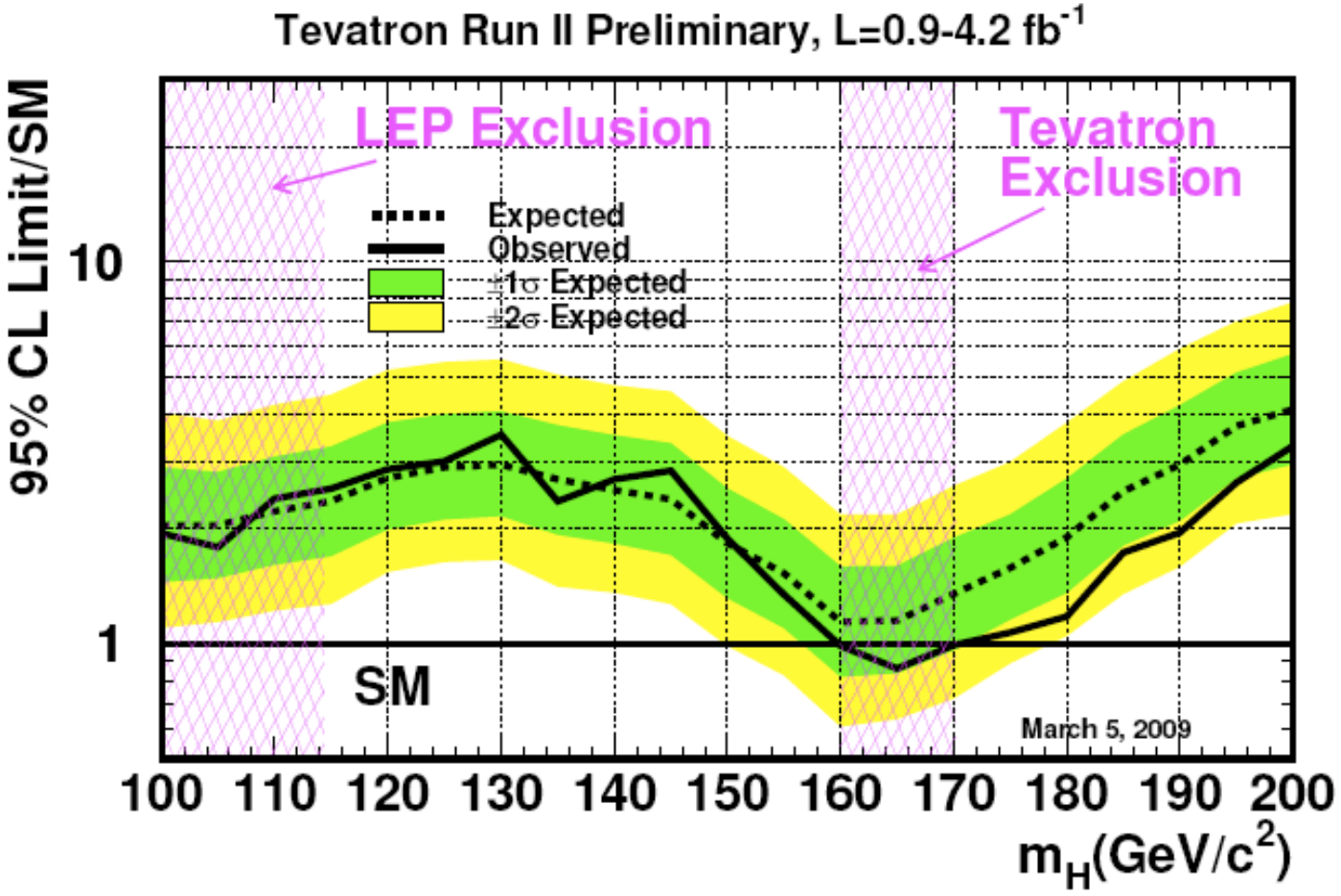
$M_H = 160$ GeV/c^2	
$t\bar{t}$	1.35 ± 0.21
DY	80 ± 18
WW	318 ± 35
WZ	14 ± 1.9
ZZ	20.7 ± 2.8
W+jets	113 ± 27
$W\gamma$	92 ± 25
Total Background	**637 ± 67**
$gg \rightarrow H$	9.5 ± 1.4
Total Signal	**9.5 ± 1.4**
Data	**654**





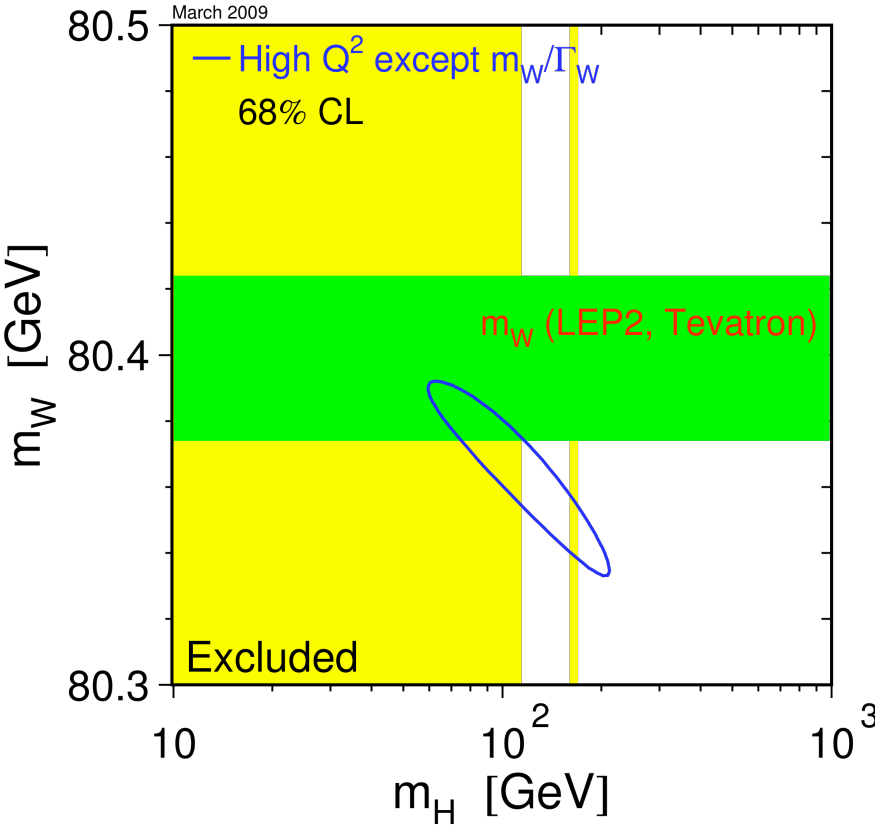
- Small signal on top of large (and uncertain) backgrounds
  - Higgs mass reconstruction impossible due to 2 neutrinos
  - Use advanced techniques (ANN etc.) to enhance S/B

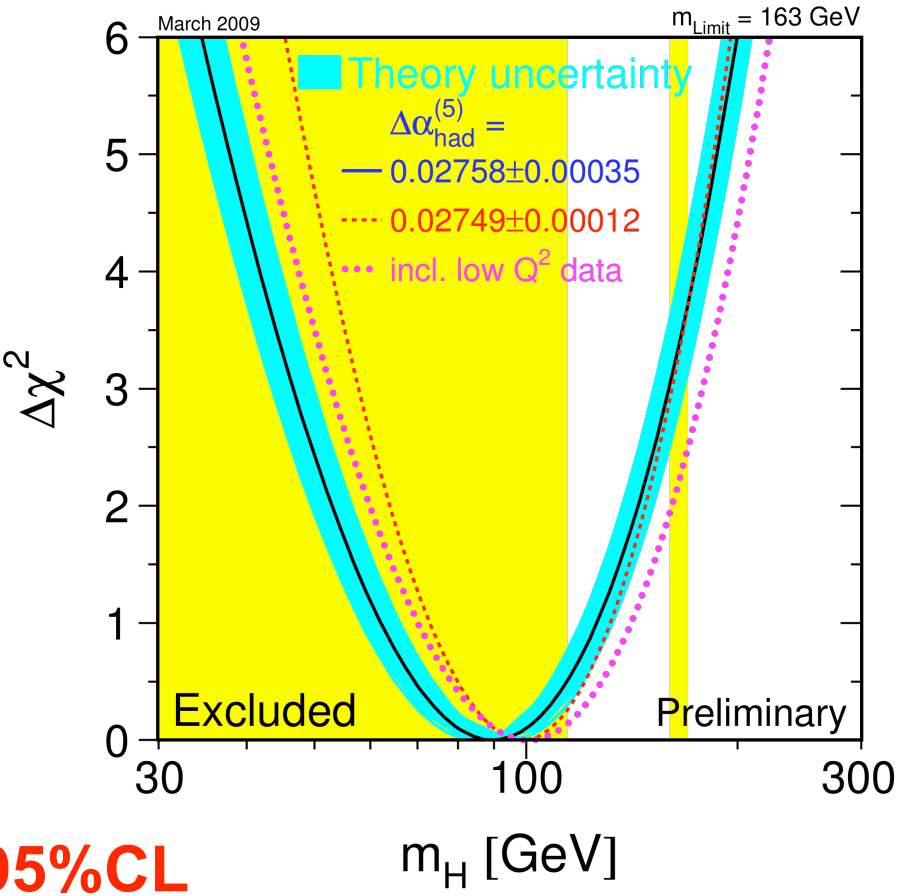
Higgs Cross Section Limit



- $160 < m_H < 170$ GeV excluded at 95% C.L.
  - Note that the limit is ~1σ better than expected
- For m_H=120 GeV: $\sigma_{limit} / \sigma_{SM} = 2.8$

M_W, m_{top} and m_{Higgs}





- **Indirectly: m_H<163 GeV@95%CL**

(caveat: is the measured top mass the pole mass?)

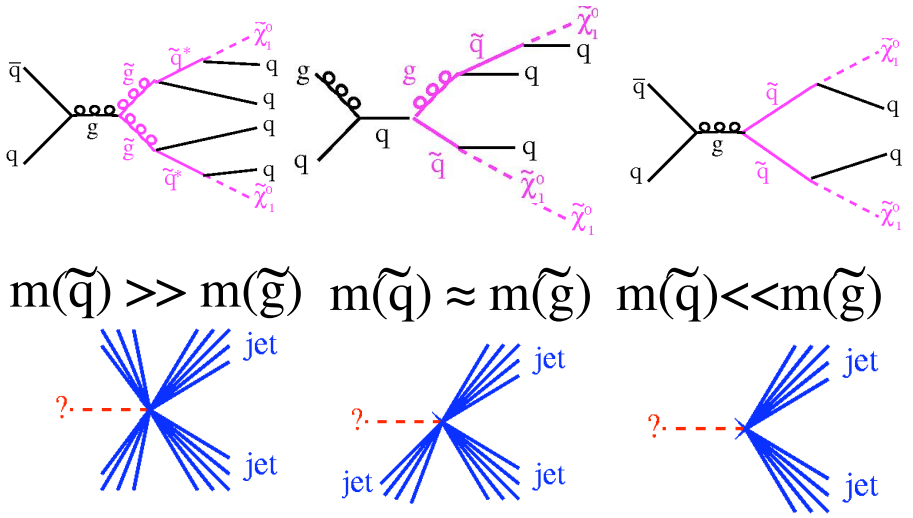
- **Directly: 114<m_H<160 GeV or m_H>170 GeV @95%CL**

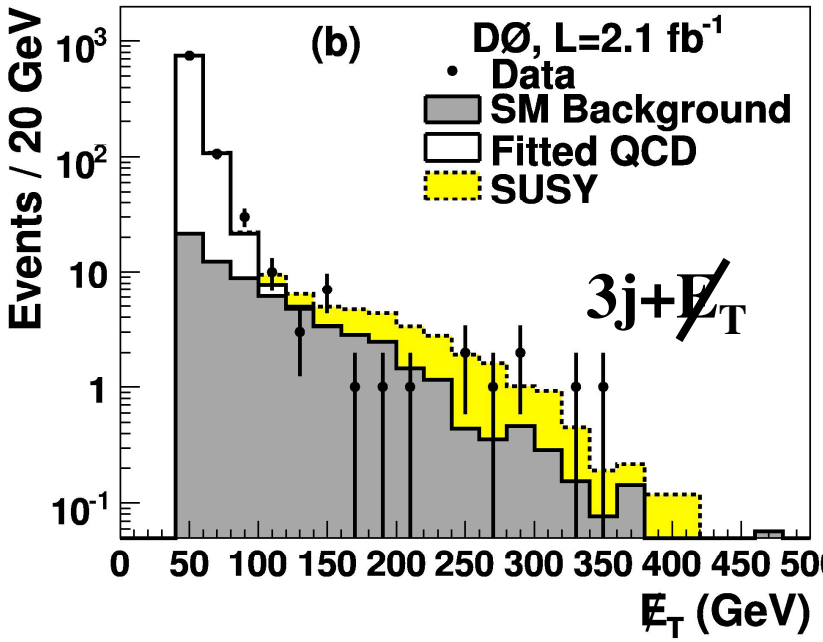
(This all assumes that there is no new physics beyond the SM)

Beyond the Standard Model

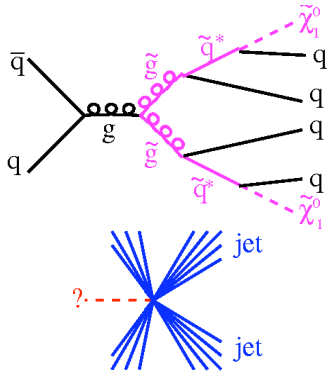
Squarks and Gluinos

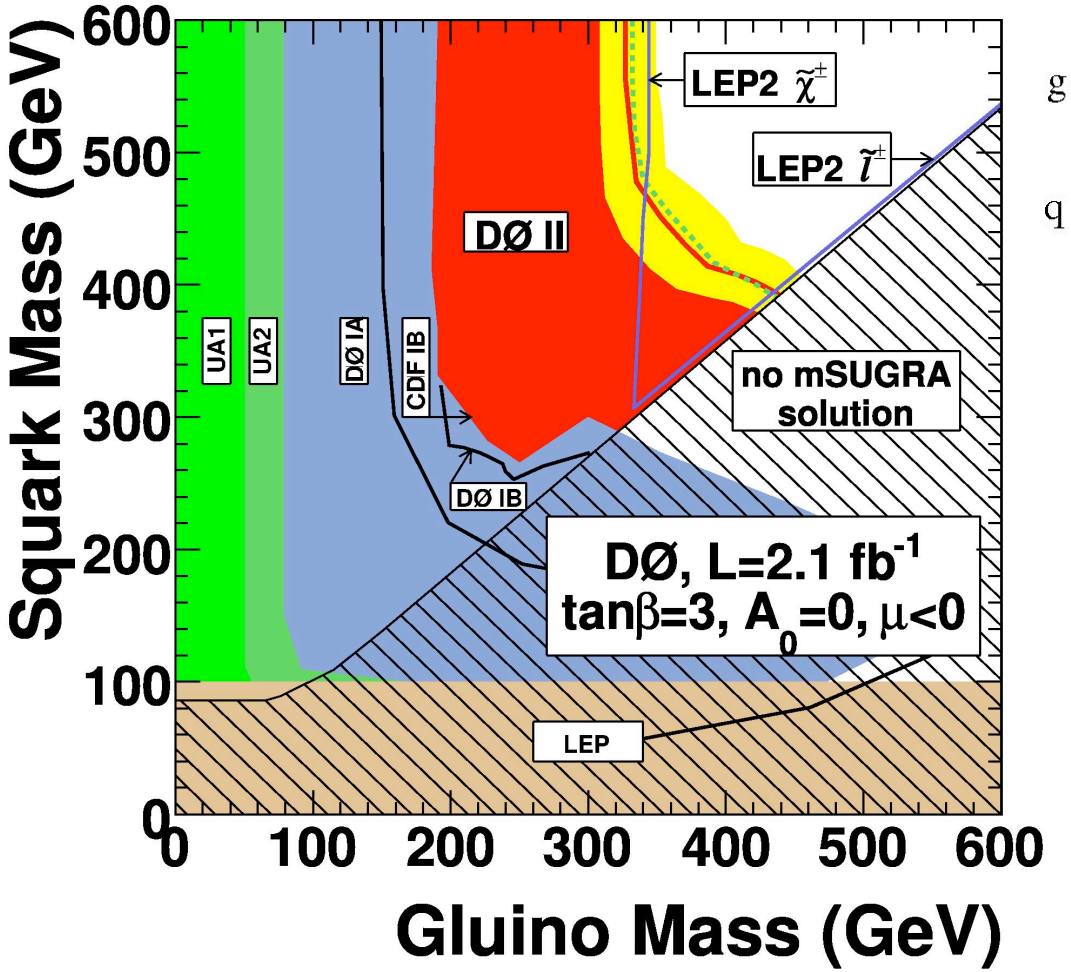
- Squark and Gluino production:
  - Signature: jets and E_T^{miss}
  - At Tevatron no long cascades to leptons expected:
    - Lepton veto applied
- Strong interaction => large production cross section
  - for $M(\tilde{g}) \approx 300$ GeV/c^2:
    - 1000 event produced/ fb^{-1}
  - for $M(\tilde{g}) \approx 500$ GeV/c^2:
    - 1 event produced/ fb^{-1}
  - Relatively little gain expected with more data
    - Need LHC!
- Analysis optimized depending on mass hierarchy

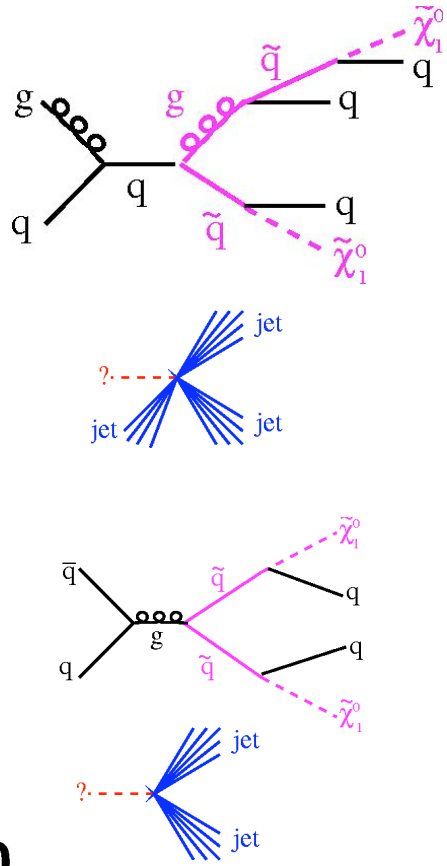




Supersymmetry Parameter Space



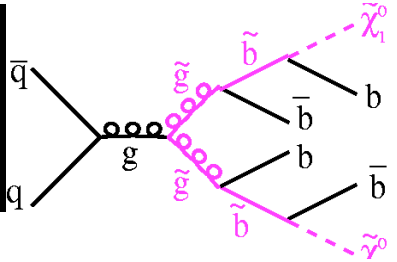




M(g̃)>308 GeV, M(q̃)>379 GeV

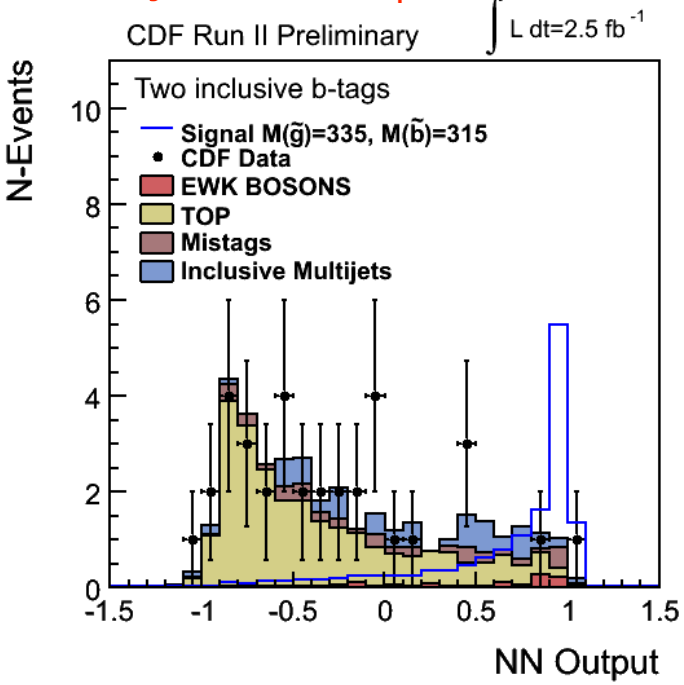
NB: up to 10 GeV differences depending on treatment of theoretical cross section uncertainties

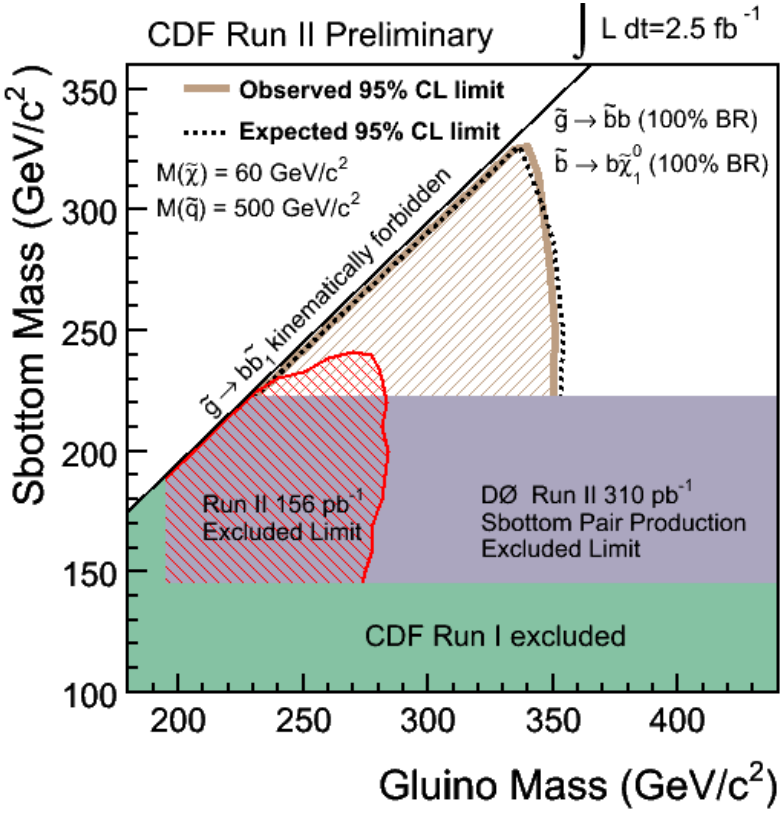
3rd generation Squarks



- 3rd generation is special:
  - Masses of one can be very low due to large SM mass
  - Particularly at high tanβ
- Search for sbottom quarks from gluino decays
  - 2 b-jets and E_T^{miss}

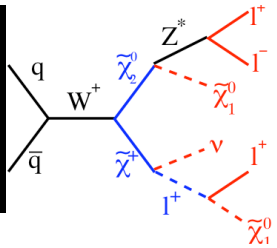
$$m^2_{\tilde{b}_{1,2}} = \frac{1}{2}\left(m^2_{\tilde{b}_L} + m^2_{\tilde{b}_R}\right) \mp \frac{1}{2}\sqrt{\left(m^2_{\tilde{b}_L} - m^2_{\tilde{b}_R}\right)^2 + 4m_b^2(A_b - \mu\tan\beta)^2}$$

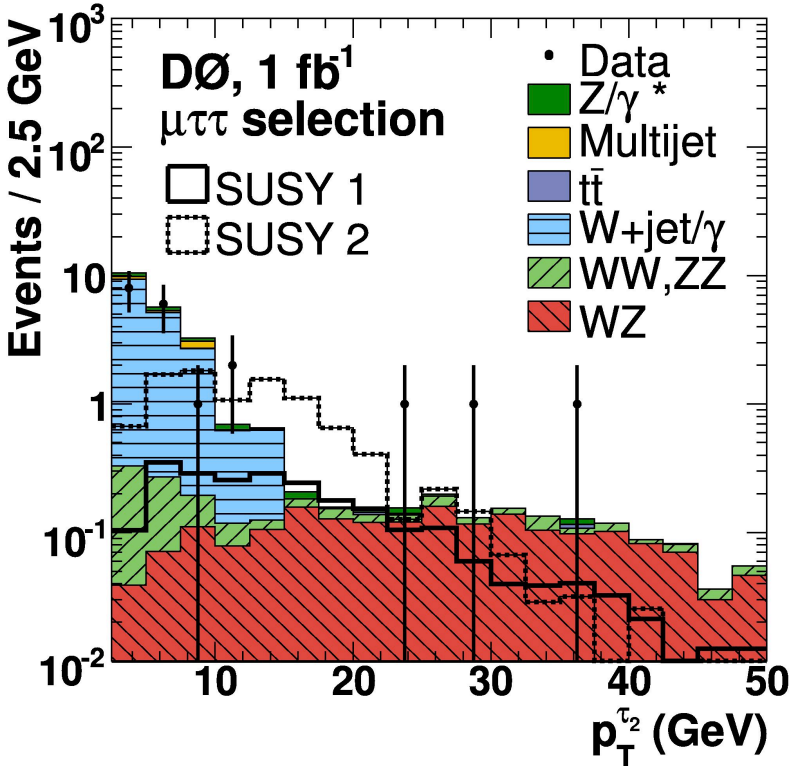


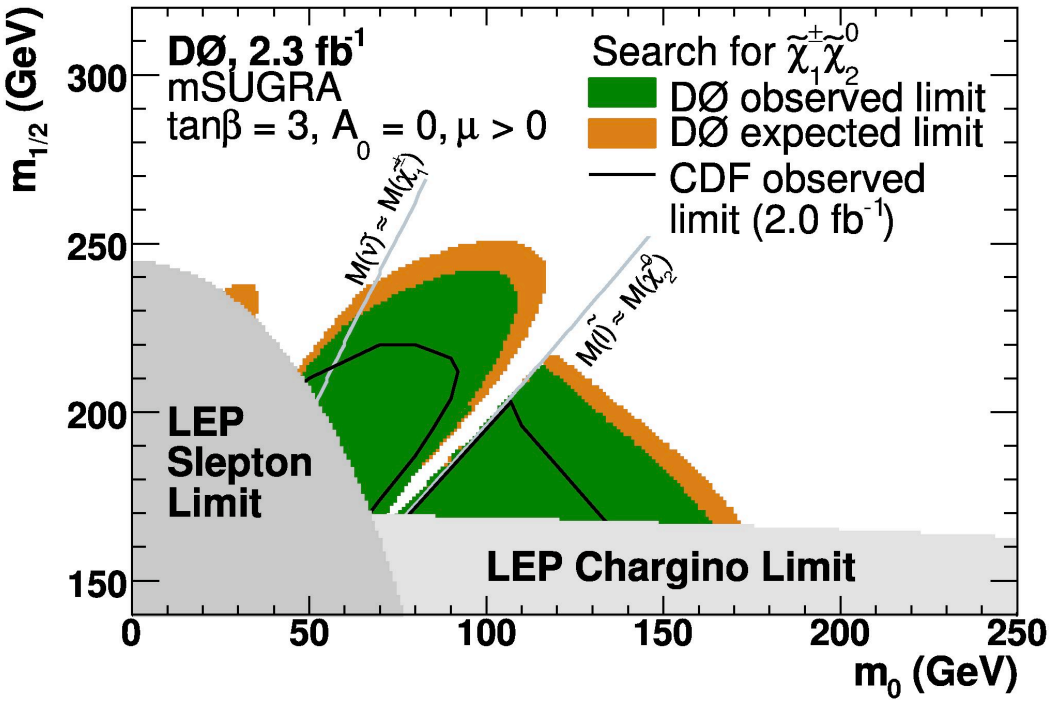


Searches in stop sector also performed and no signal found

SUSY Trileptons

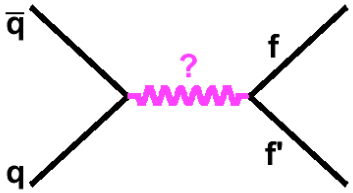




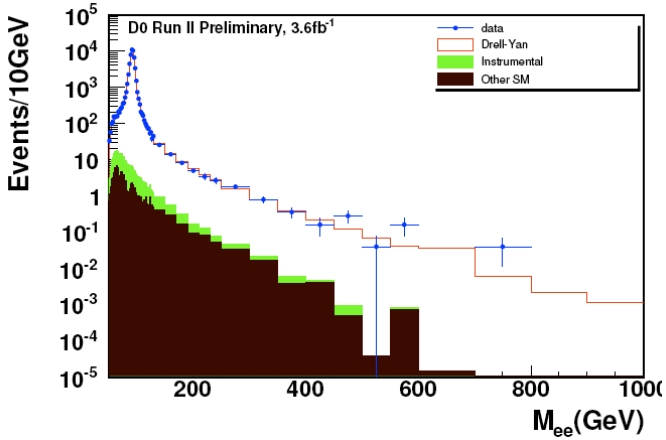


- Search for direct chargino-neutralino production decaying to leptons
- Data consistent with background expectations
  - Exceeds limit on chargino mass from LEP at low tanβ
  - rather model-dependent though

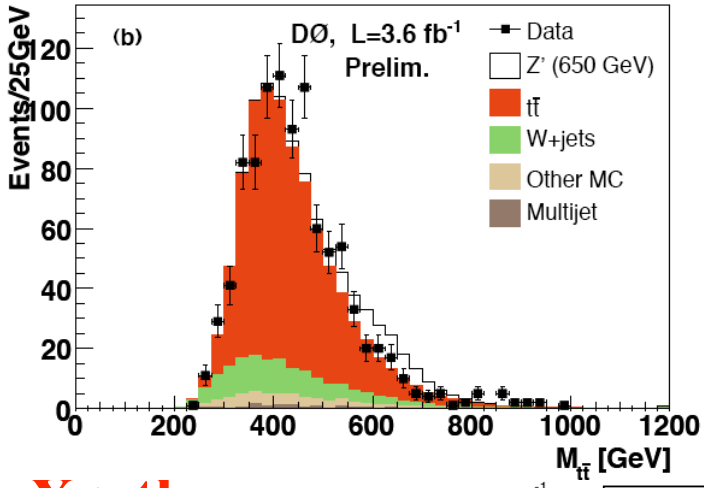
Resonance searches: W', Z',...



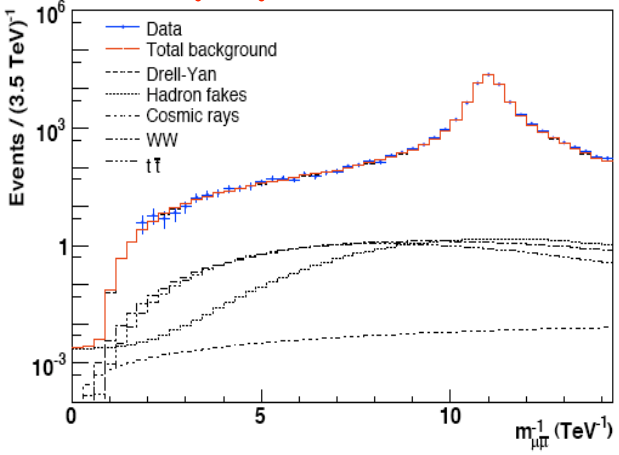
X->e⁺e⁻



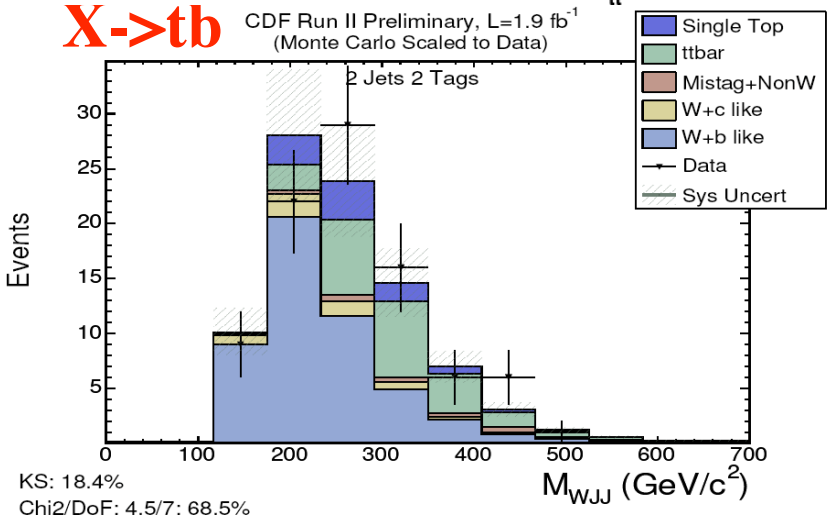
X->tt



X->μ⁺μ⁻



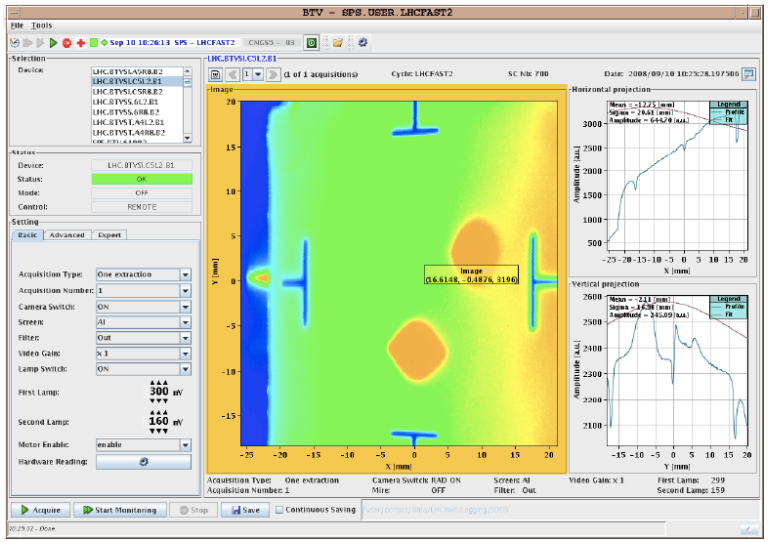
X->tb

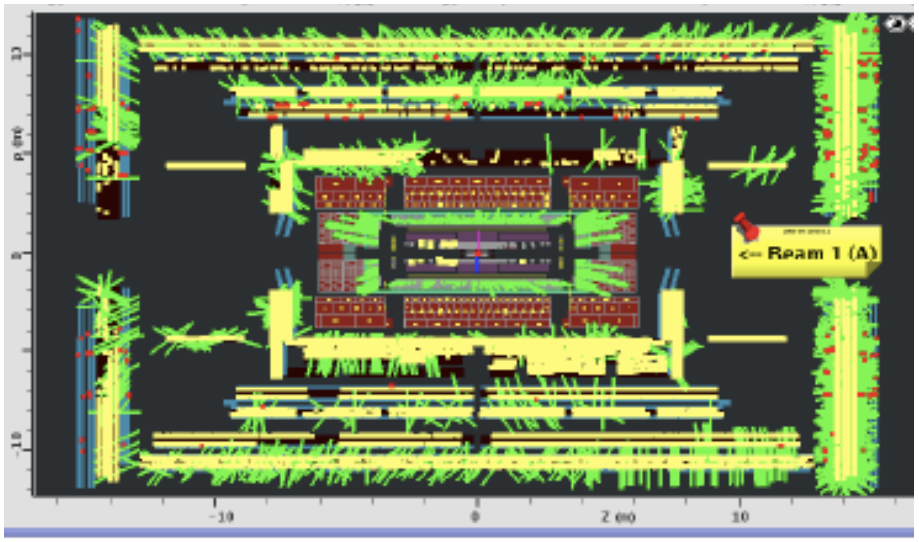


- Many searches for new resonances
  - None found yet: limits are about 0.7-1 TeV

LHC Perspectives

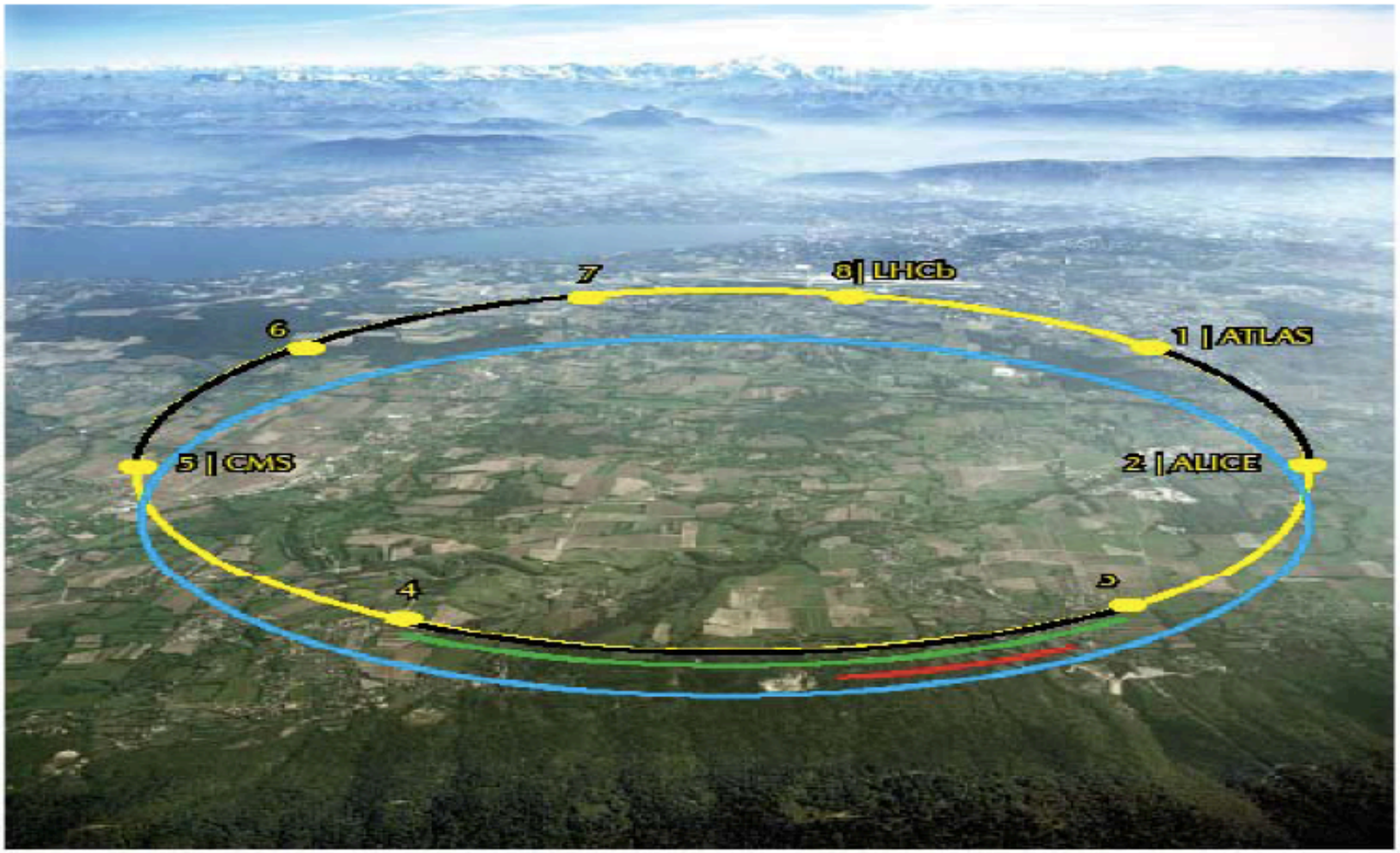
LHC Status and Schedule





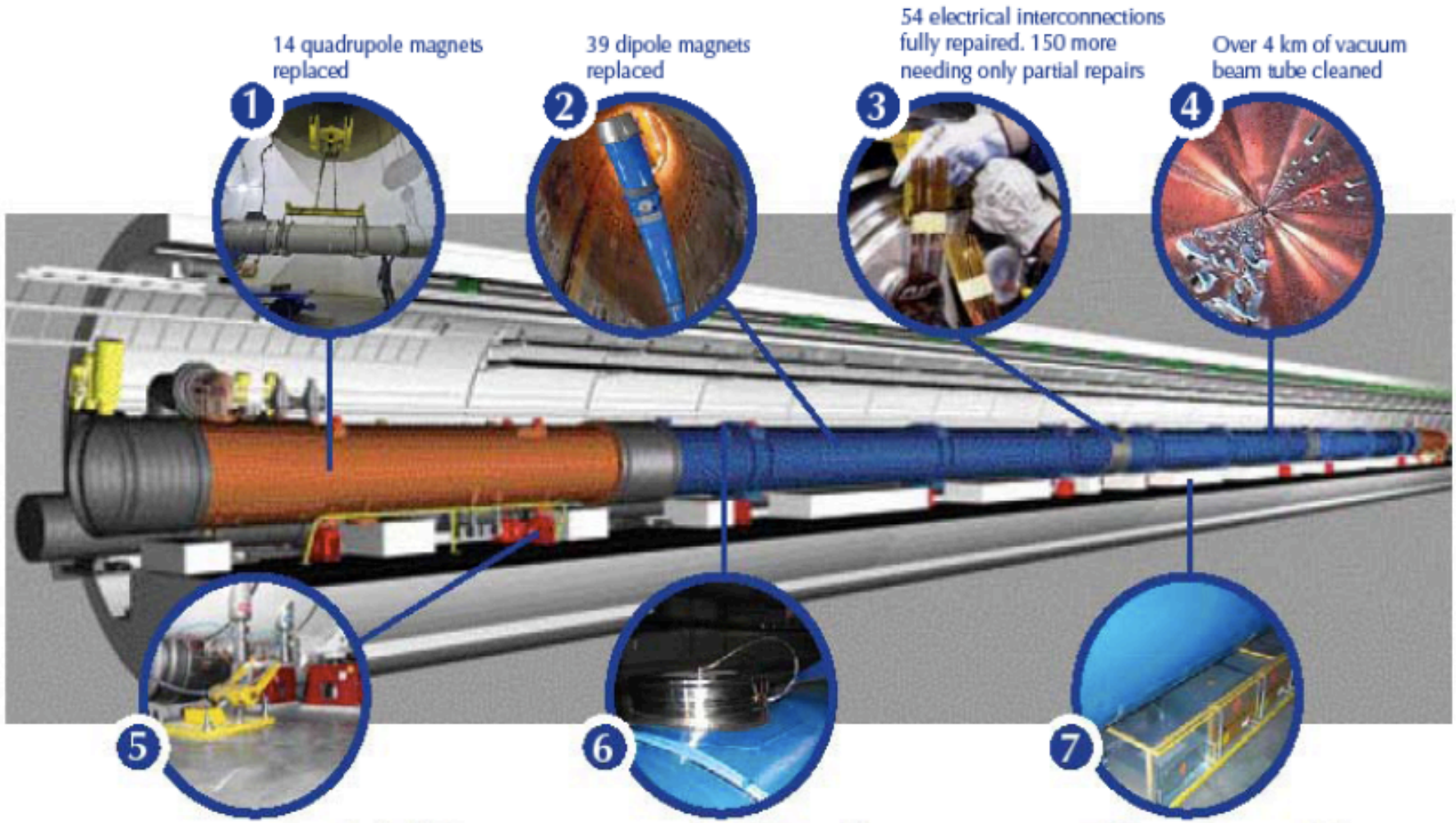
- First beam on September 10th 2008
  - Major incident in sector 34 9 days later
    - first collisions delayed until end of this year
  - LHC will be ready for beam again end of October
    - Energy per beam: 4-5 TeV
    - Run for about 9-12 months and get L~200 pb^{-1}

Where the repairs are happening

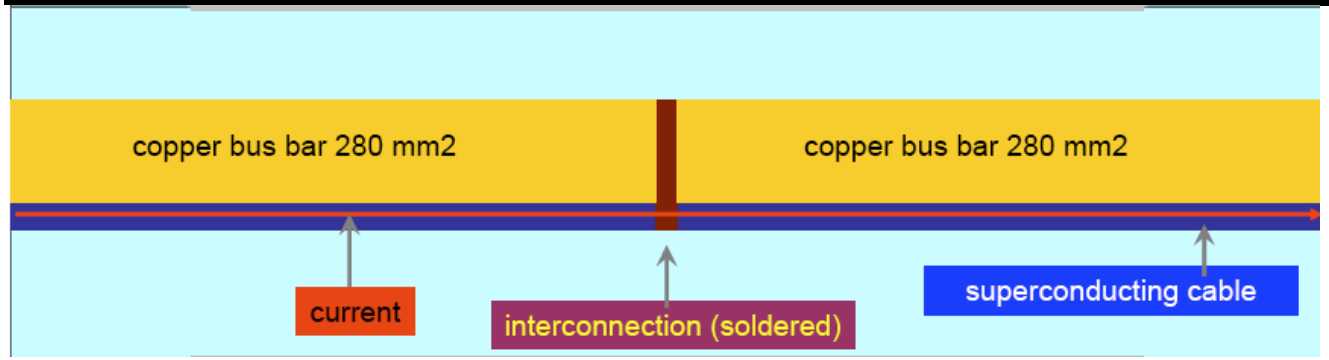


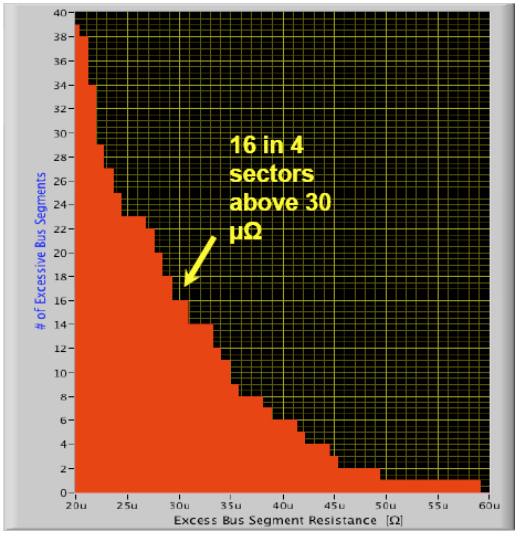
New pressure release ports fitted
Upgrade of magnet protection system
Cleaning ofvacuum beam tube
Dipole and quadrupole magnets replaced and electrical interconnections
LHC ring

The LHC repairs in detail

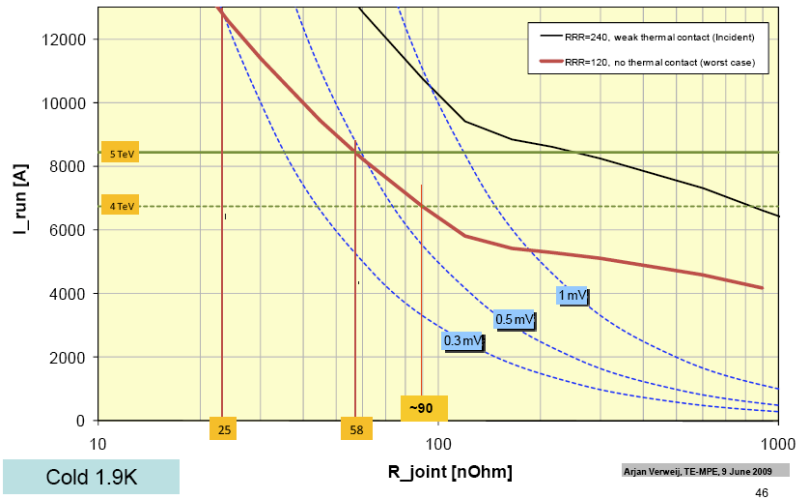


Splice Resistance Measurements

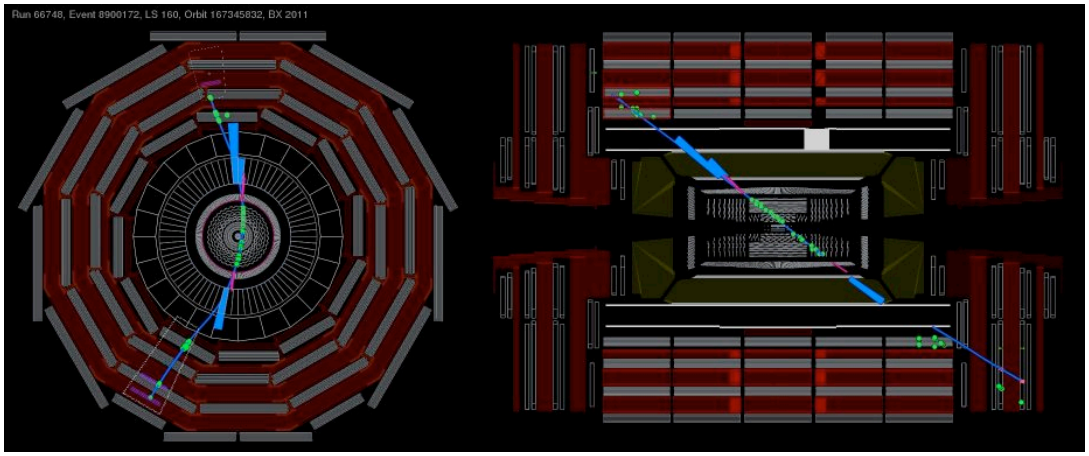


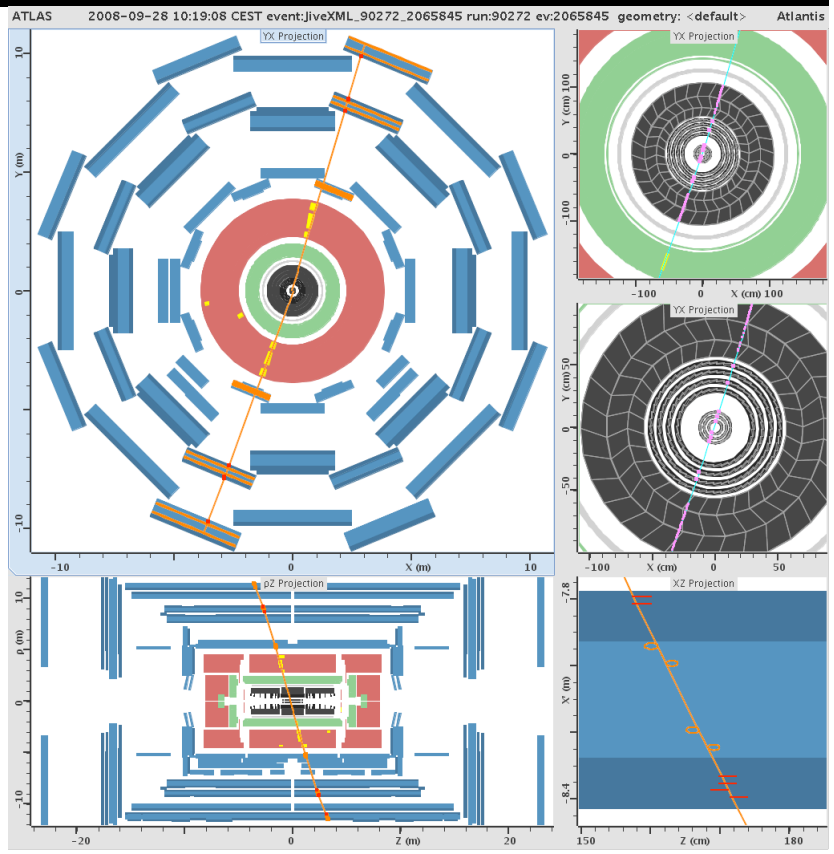


- Sector 34 incident caused by **splice connection having higher resistance** than tolerable
  - Also now found in other magnets (up to 59 μΩ)
  - Danger in case of quench
- may **limit beam energy to 4 TeV** depending on what is found in other sectors
  - Will know in August



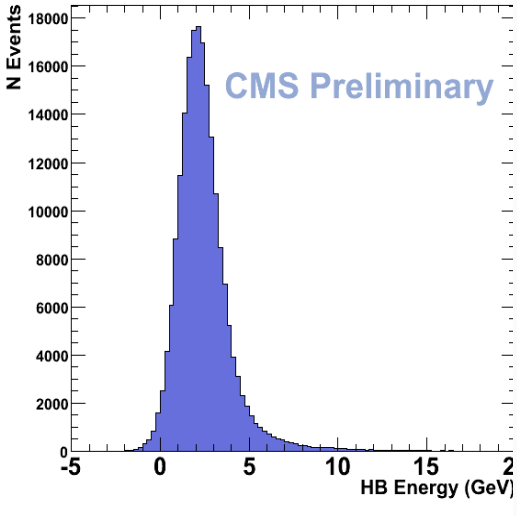
Cosmic Data Taking End of 2008

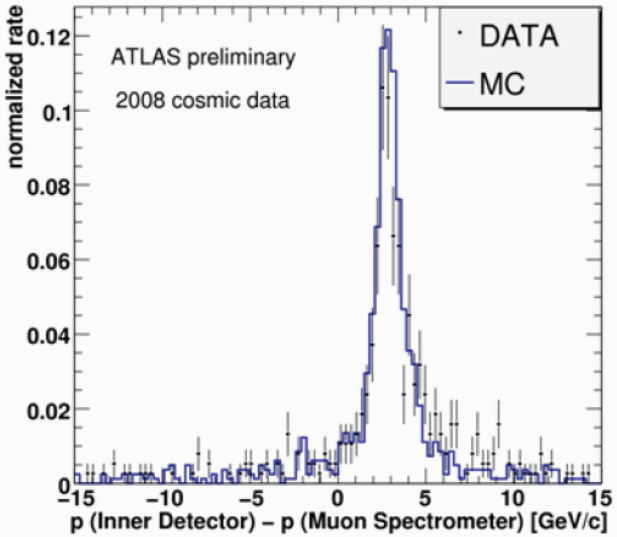


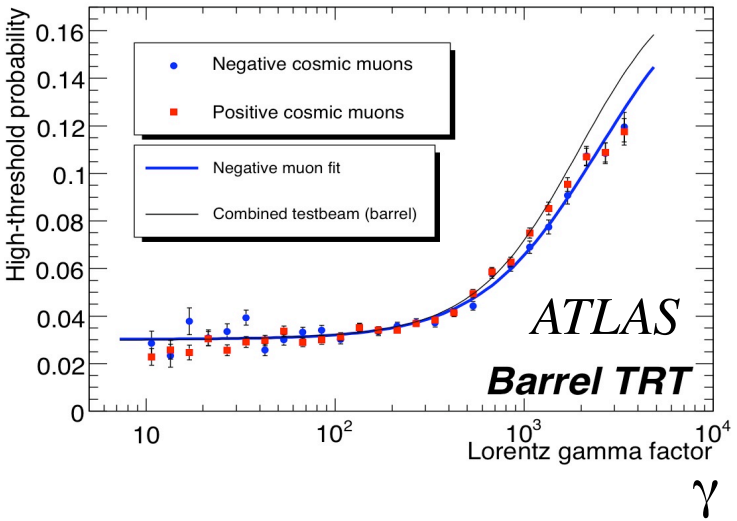


- After September incident
  - cosmic ray data taking of full detectors
  - Great operational experience
  - Allowed in-situ performance studies

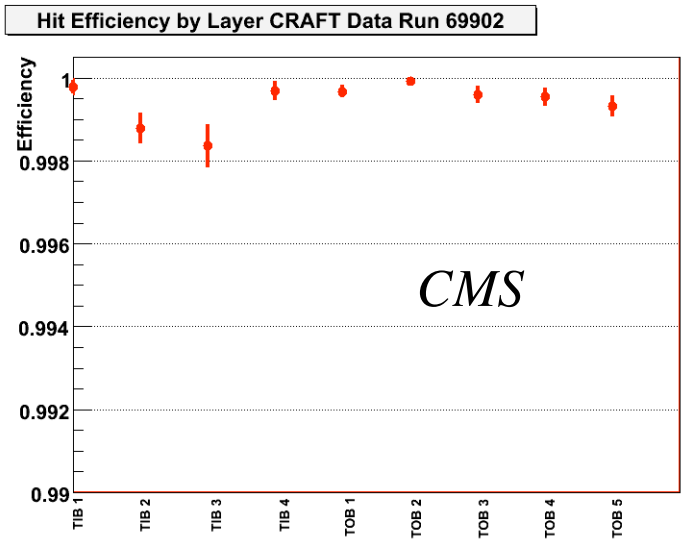
ATLAS and CMS Detectors work!







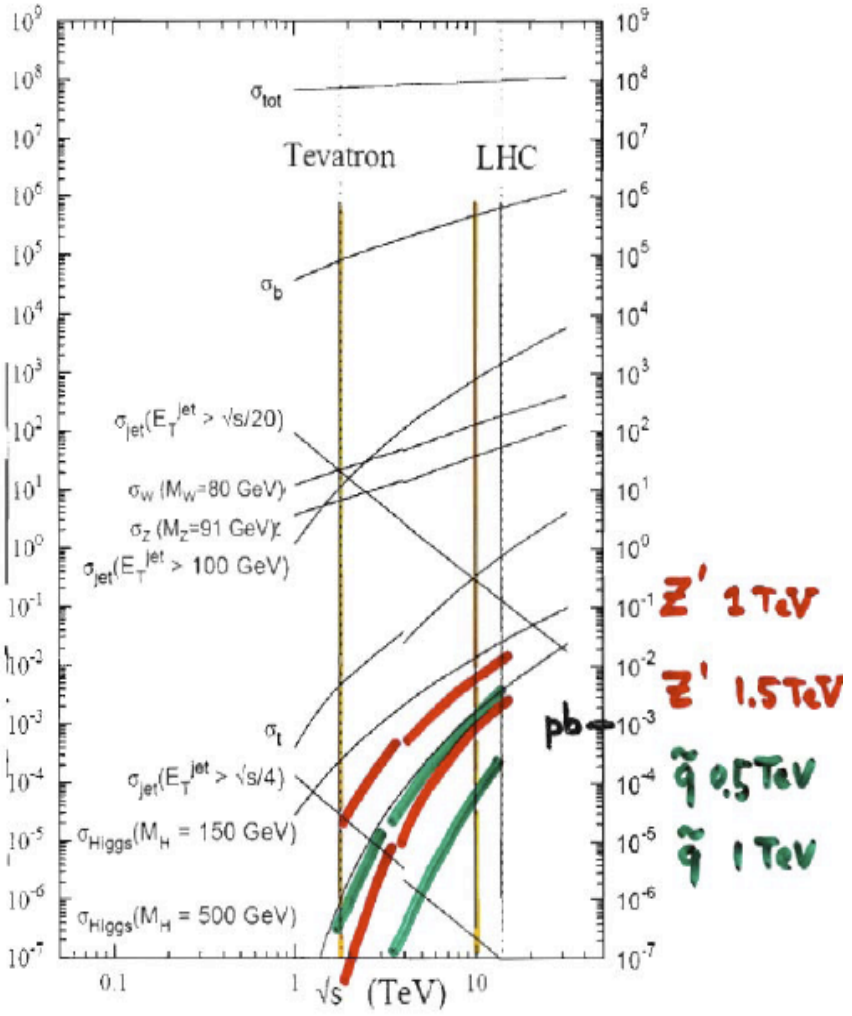
- **Good performance of all systems in both ATLAS and CMS**
  - **E.g. noise and energy scale in calorimeters**
  - **E.g. alignment of trackers and muon spectrometers started and already ok for physics**



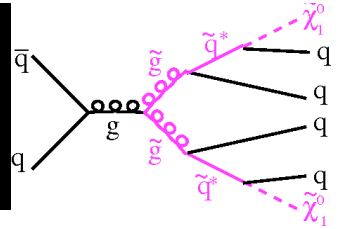
LHC Physics Prospects

- Amazing prospects on longer term at √s=14 TeV, e.g.
  - Find or exclude SM Higgs boson over full mass range with >10 fb^{-1}
  - Probe SUSY up to 1.5 TeV already with 1 fb^{-1}
- Reduced potential with 200 pb^{-1} at 10 TeV:
  - Higgs boson: too little data to compete with Tevatron
  - High Mass (Z', SUSY, …): extend discovery reach beyond Tevatron

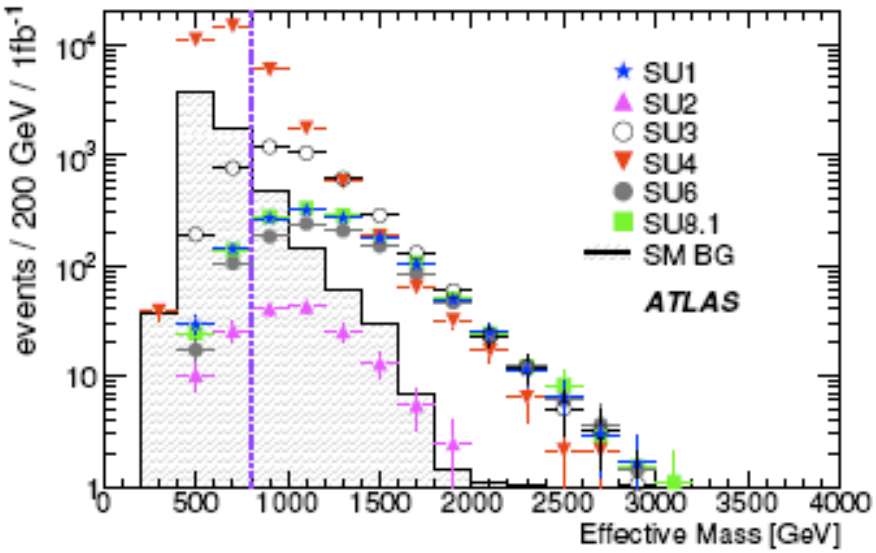
M. Schmaltz, BU

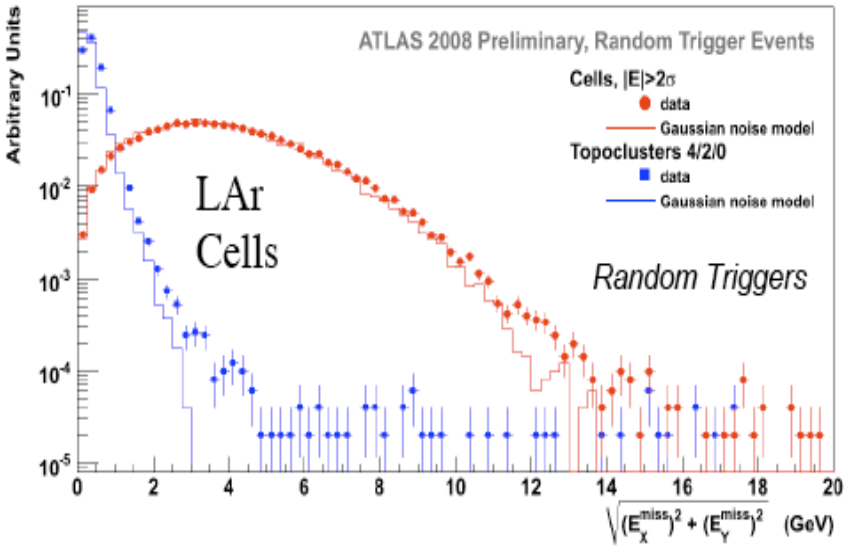


SUSY Search: Jets + E_T^{miss}

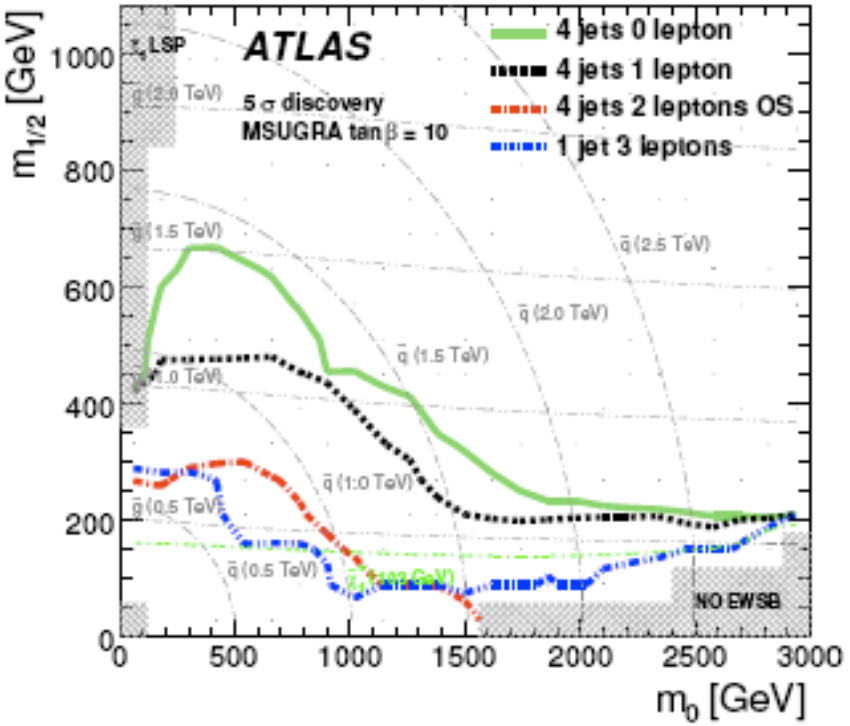


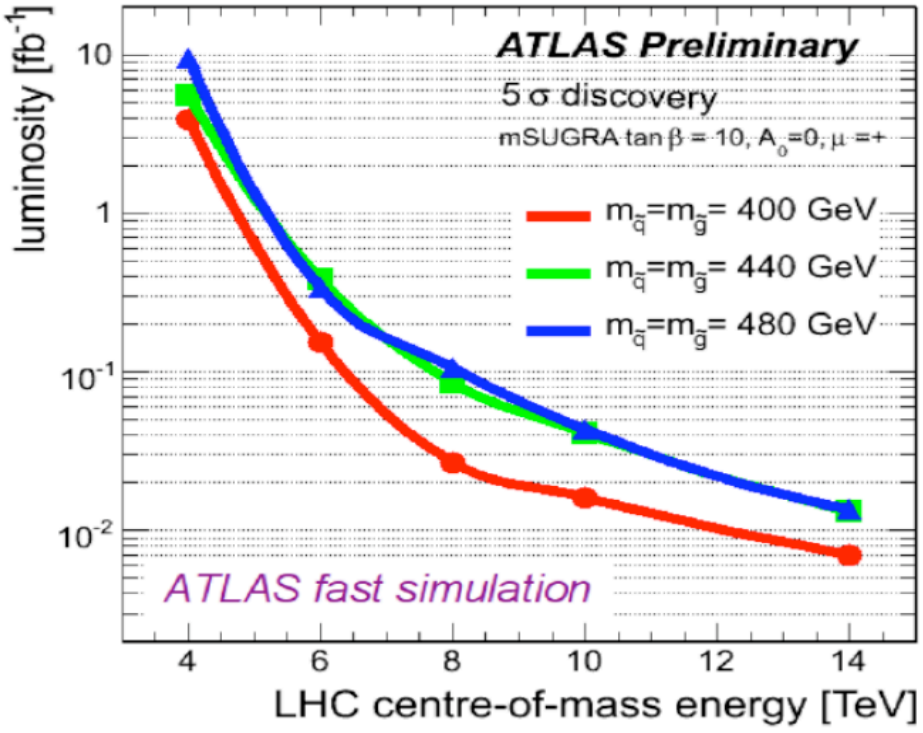
- Classic $\tilde{q}$ and $\tilde{g}$ search
  - ≥ 4 high E_T jets
  - Large E_T^{miss}
  - $M_{eff}=E_T^{miss}+\Sigma E_T^{jet}$
- Understanding of E_T^{miss} critical
  - Major progress during 2008 cosmics run





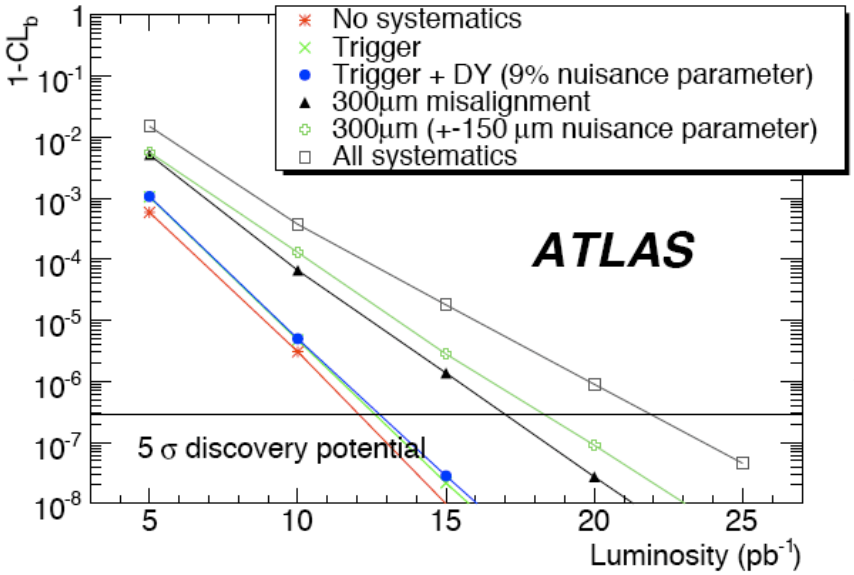
SUSY Discovery Reach

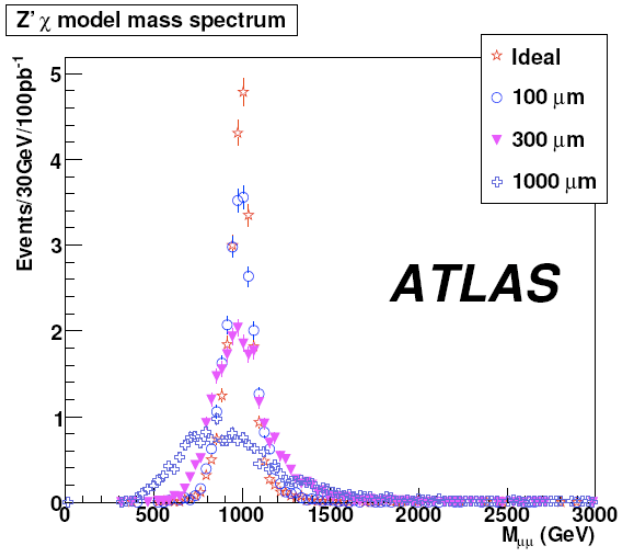


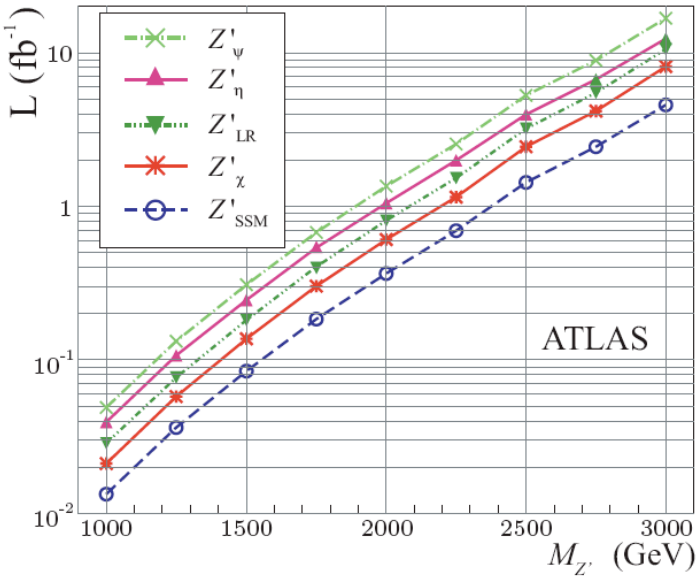


- Discovery potential beyond Tevatron:
  - $\sqrt{s} \geq 8$ TeV: requires $L \geq 20$ pb^{-1}
- With 1 fb^{-1} will probe masses up to 1.5 TeV

Resonance Search: Z'







- Early physics topic
  - Improve upon Tevatron with >20 pb^{-1}
  - Depends on muon spectrometer alignment

Conclusions and Outlook

- **Tevatron, CDF and DØ are operating well**
  - Tevatron delivered 7 fb^{-1} by now !
  - Running guaranteed until Fall 2010 (9.5 fb^{-1})
- **Physics results cover broad range:**
  - **Higgs boson constraints at 95% CL**:
    - Indirect (m_W and m_{top}): m_H<163 GeV/c^2
    - Direct searches: m_H<160 or >170 GeV/c^2
  - **Searches** beyond the Standard Model
    - no sign of new physics yet: m($\tilde{g}$)>300 GeV, m(Z')>1 TeV, …
- **LHC startup in 2008 successful**
  - **Unfortunately compromised by major incident shortly after start**
    - Required major repairs of one sector and installation of additional components in other sectors
    - Restart expected for end of October 2009
    - Goal: take about 200 pb^{-1} with $\sqrt{s}$=8-10 TeV until end of 2010
      - Exceed discovery potential of Tevatron in high mass range
  - **Meanwhile detectors have gained operational experience and improved their performance with cosmic rays**
- **Hopefully Higgs boson and/or New Physics will be found soon!**

More details in Parallel Sessions

- See parallel session talks:
  - LHC:
    - A. Barr, S. Krutelyov, R. Gnozalez-Suarez
  - Tevatron:
    - A. Garcia-Bellindo,A. Meyer, C. Hensel, A. Ruiz-Jimeno, M. Kreps